Relationship between electricity prices, consumption and economic growth in South Africa

A Dissertation

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by

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Dedication

This paper is dedicated to my family; my husband, my kids, my mother, my brother and my dad who passed away in 2014. His memories live on.

Acknowledgements

When I embarked on this journey I knew that it was not going to be an easy one. Firstly, I would like to extend my greatest appreciation to my supervisor who is so efficient Sean Gossel. Thank you for all the guidance and support throughout this process.

To my kids, thank you for understanding that mummy was busy. To the father of my kids, I know it was tough to do everything on your own. I truly appreciate the support and the encouragement.

Not forgetting my colleagues who ensured that things don’t fall apart at work, thank you for the support.

Lastly, thank you God.

Abstract

This study analyses the relationship between electricity prices, consumption and economic growth at national and per sector levels in South Africa over the period from 2006 to 2017 using the auto-regressive distributed lag (ARDL) bounds testing approach and error correction model (ECM). With regards to electricity consumption, in the mining and residential sectors, the relationship between electricity consumption and GDP is insignificant and thus adheres to the neutrality hypothesis. In contrast, in the services, transportation and industrial sectors, there is a positive relationship between GDP and electricity consumption, which adheres to the conservative hypothesis. Lastly, the agricultural sector has a positive relationship between electricity consumption and economic growth in the short run, and thus adheres to the growth hypothesis.

In the case of electricity prices and electricity consumption, the results find that the relationship is insignificant on a national basis and this is true for the services, transport, residential and agricultural sectors too, whereas there is a negative association with electricity consumption in the mining sector while the industrial sector has a negative association with electricity prices.

The results for the relationship between electricity prices and electricity consumption show that in the national, services sector, transport sector, residential and agricultural sectors, electricity consumption has an insignificant relationship with the electricity prices. This is in contrast to the mining sector, whose electricity consumption is negatively associated with electricity prices while the industrial sector electricity consumption has a positive and significant relationship with electricity prices.

With regards to the relationship between electricity prices and GDP, the results find that there is an elastic association in the national, services, mining, and industrial sectors with a negative impact on the GDP in the long run. In contrast, the relationship between electricity prices and GDP in the transport and residential sectors is insignificant.

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List of Acronyms and abbreviations

ADF	Augmented Dickey-Fuller test
AGR	Agriculture
ANC	African National Congress
ARDL	Auto-Regressive Distributed Lag Model
c/kWh	Cents per kilowatt hours
CUSUM	Cumulative Sum of recursive residuals
DW	Durbin-Watson
EC	Electricity Consumption
ECOWAS	Economic Community of West States
Elect_Con	Electricity Consumption
Elect_Pri	Electricity Prices
EMP	Employment
EP	Electricity Prices
GCC	Gulf Corporation Council
GDP	Gross Domestic Product
GDP_G	Economic growth
GFCF	Gross Fixed Capital Formation
IND	Industrial
IRENA	International Renewable Energy Agency
KPSS	Kwiatkowski, Phillips, Schmidt, and Shin
kWh	Kilowatt hours
MIN	Mining
MYPD	Multiple Year Price Determination
NDP	National Development Plan
NERSA	National Energy Regulator South Africa
OECD	Organisation for Economic Cooperation and Development
PP	Phillips-Perron
RCA	Regulatory Clearing Account
RES	Residential

RSA	Republic of South Africa
SDGs	Sustainable Developmental Goals
SEC	Sector level
SER	Services
TRA	Transport
TRD	Trade
TVP	Time Varying Parameter
TWh	TeraWatt hours
TYDL	Toda-Yamamoto Panel Approach
UAE	United Arab Emirates
VAR	Vector autoregressive model
VECM	Vector Error Correction Model

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1. Chapter 1: Introduction

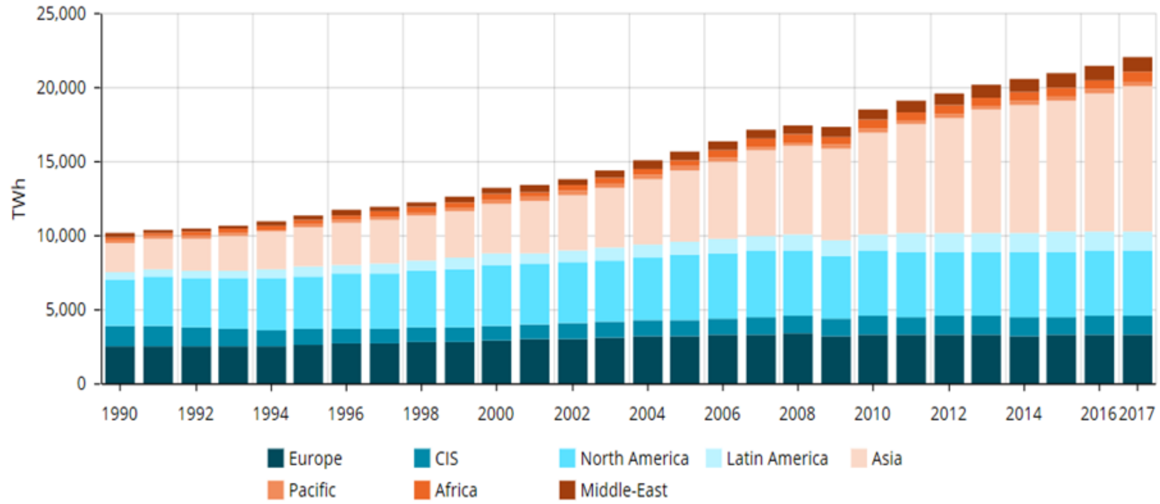
1.1 Background to the study

Electricity plays an important role in economic growth in the world for both developed and developing countries (Sekantsi & Okot, 2016). According to the World Bank, access to energy is essential for reducing poverty but there are still 840 million people (in 2017) globally without access to electricity. This is down from 1.4 billion people in 2010, which means that 89% of the world population now has access to electricity (www.worldbank.org).

In 2015, the United Nations established 17 global sustainable developmental goals (SDGs) to address the global challenges such as poverty, inequality, climate, environmental degradation, prosperity and peace and justice (UN, 2015). Goal 7 states that countries must seek to address the challenge of "access to affordable, reliable, sustainable and modern energy for all". Electricity plays an important role in the production and consumption of goods and services within an economy (Payne, 2010). The world energy consumption grew by 2.6% in 2017 (Figure 1) with China being the largest consumer of electricity, growing by 5.9% since 2014 (IEA, 2018).

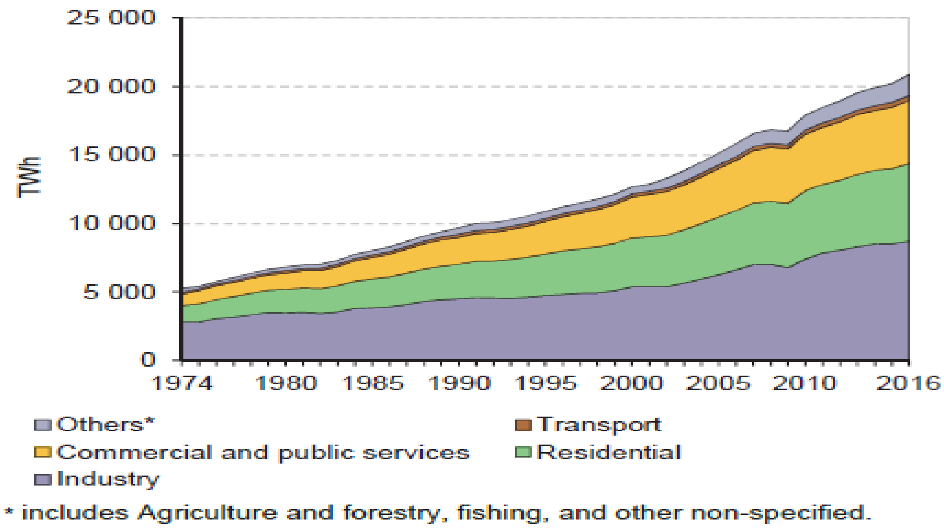
African electricity consumption has increased from 379 TeraWatt hours (TWh) in 2000 to 663TWh (Figure 1) in 2017 which is 3% of the world consumption, however the continent is experiencing power supply challenges (IEA, 2018). According to International Renewable Energy Agency (IRENA) (2015), about 30 countries in Africa are experiencing power outages and load shedding due to lack of electricity infrastructure, growing population and high electricity prices. Even though Africa is facing these challenges, the continent is moving from a generation capacity that was predominantly fossil fuels to generation mix that is embracing the new renewable electricity technologies. The renewable electricity technologies have increased by 10% since 2007 (IEA, 2018). North Africa continues to grow hydropower whereas the rest of the continent will have a mix of renewable energy supply, such as wind power and concentrated solar power and the renewable energy in the generation mix will grow over 50% by the year 2030 (International Renewable Energy Agency (IRENA), 2015). Africa is a continent with enormous socio-economic issues, there are various benefits of moving from traditional use of biomass to renewable energy and the benefits are the improvement of the economy, as this will also improve human health which will result in budget reduction on the government expenditure.

Figure 1: World electricity consumption trends



As can be seen from Figure 2 below, while the world energy consumption has increased over the years, the industrial sector is still the largest consumer of electricity, followed by the residential sector. However, the move from the use of fossil-fuel energy generation to renewable energy generation is still slow with 65.5% of world generation production from fossil fuels (IEA, 2018).

Figure 2: World consumption per sector



IEA, 2018

1.2 South Africa Electricity Trends

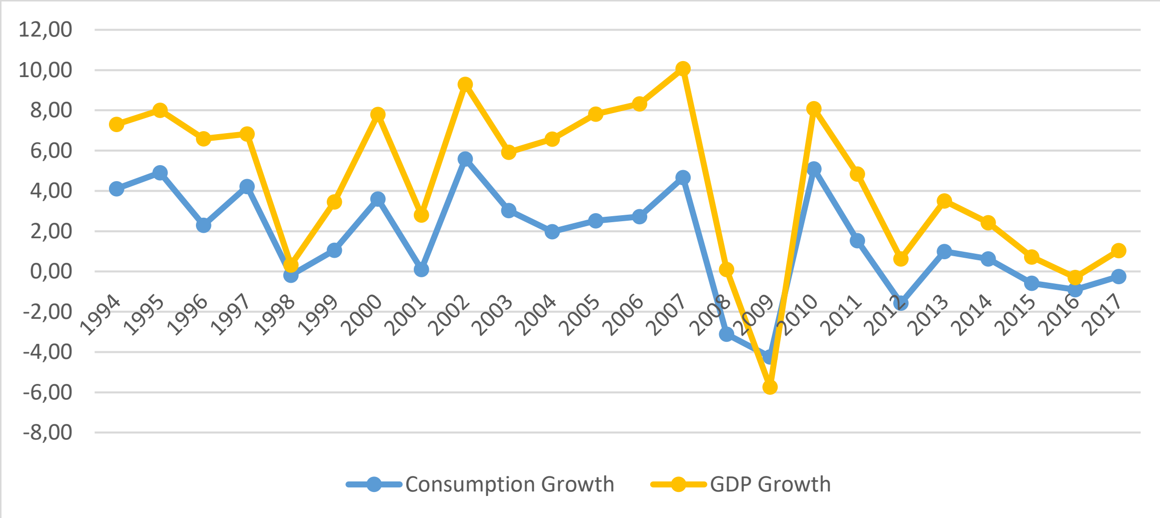
South Africa (SA) is the highest consumer of electricity in Africa at 209 TWh in 2017 and is ranked the 21st top electricity user in the world (www.cia.gov). Eskom is the national power utility (primary electricity supplier) established in 1923 and generates 90% of electricity used in South Africa. Eskom sells electricity to distributors who then resell to residential consumers, commerce and industry. Electricity is generated by combination of fossil fuel and renewable energies such as coal (91%), nuclear (6%), pumped storage (2%), hydro (0.32%), wind (0.15%) and open gas turbines (0.053%) (Eskom - Annual Financial Statements, 2018). South Africa is thus still highly dependent on fossil fuels. In addition to generation, the utility also transmits and distributes to industrial, mining, commercial, agricultural, residential and redistributors (www.eskom.co.za).

Over the past 30 years, South Africa's economy has transitioned away from its historical dependence on the energy-intensive mining and manufacturing sectors towards being a more diversified services-based economy (Deloitte, 2017). In 1975, mining, manufacturing and construction accounted for almost half of the GDP at 45%, since declining to 30% in 2015. In contrast, the services sector has grown from 13% of GDP to 22% of GDP over the same period (www.sarb.gov.za).

According to Costantini & Martini (2010), electricity consumption is a significant component of economic growth. However, as can be seen from Figure 3, electricity consumption in South Africa has been decreasing since 2013 in tandem with a declining GDP growth. South Africa experienced rapid growth in electricity consumption after the early 1990s due to the economy's structural changes (Inglesi & Blignaut, 2011). When the African National Congress (ANC) came into power in 1994, access to electricity was mainly limited to white South Africans, including remote farms; with only a few black South Africans having access (Eberhard, 2005). One of Eskom's first mandates under the new government was thus to accelerate electrification to the previously disadvantaged. The households connected to the electricity grid then increased from 35% in 1990 to 84% in 2017 (Statistics SA, 2017). A breakdown of electricity consumption by sector shows that manufacturing and mining still consume the bulk (62%), followed by residential (20%), and then the other sectors, such as the commercial, public services and agriculture consumed 15% (Department of Energy (RSA), 2012).

According to Blimpo & Cosgrove-Davies (2019), the cost of electricity for many African countries is double the cost of high income countries such as the United States and far higher than many other emerging countries. However, electricity in South Africa was amongst the cheapest in the world until recently (www.statista.com). The increase in electricity prices started when Eskom experienced a shortage of electricity supply in 2007/2008 (Eskom Revenue application MYPD 4, 2018). Eskom's generation challenges were, however, predicted two decades ago, but the utility failed to invest in new power plant infrastructure (Department of Minerals and Energy, 1998). Between 1998 and 2004, Eskom was denied funding to build new capacity as government did not have a clear policy on energy (Pollet, Staffell, & Adamson, 2015).

Figure 3: Electricity consumption growth and GDP growth

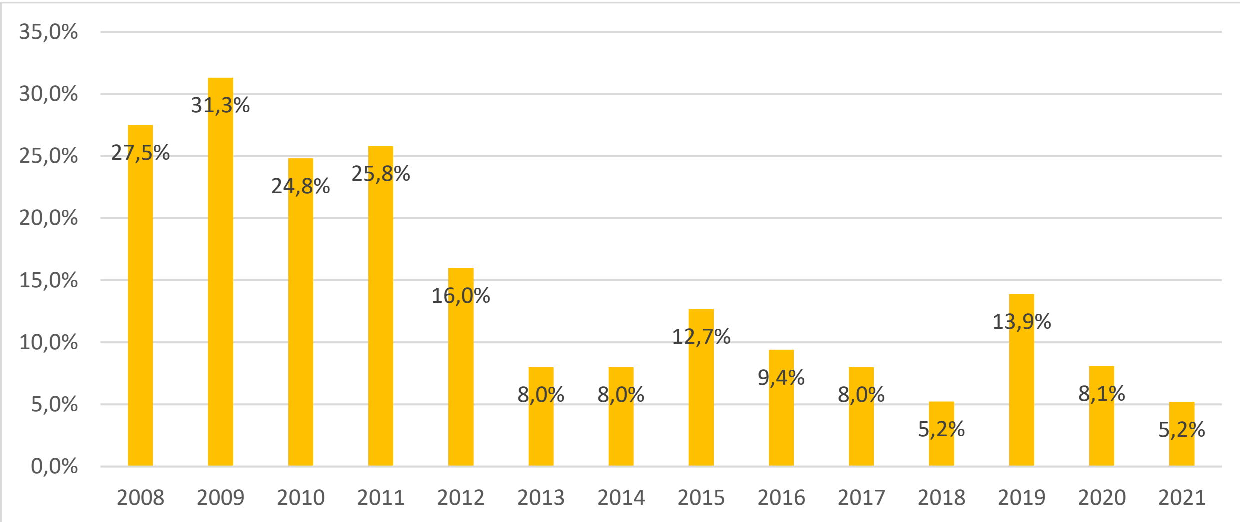


Source: Eskom; World Bank; Statistics SA

1.3 South African Electricity Prices

The price of electricity is determined by the regulator and through the supply and demand in the market. As can be seen from Figure 4 below, between 2008 and 2012, NERSA was approved for double digits tariff increases of consumer price inflation plus 2%, which had a negative impact on the economy. According to Inglesi-Lotz & Pouris (2016), electricity prices are a determinant of electricity demand and thus an essential input cost of production. M. E. Bildirici, Bakirtas, & Fazil;, (2012) argue that high increases in electricity could result in reduced production competitiveness.

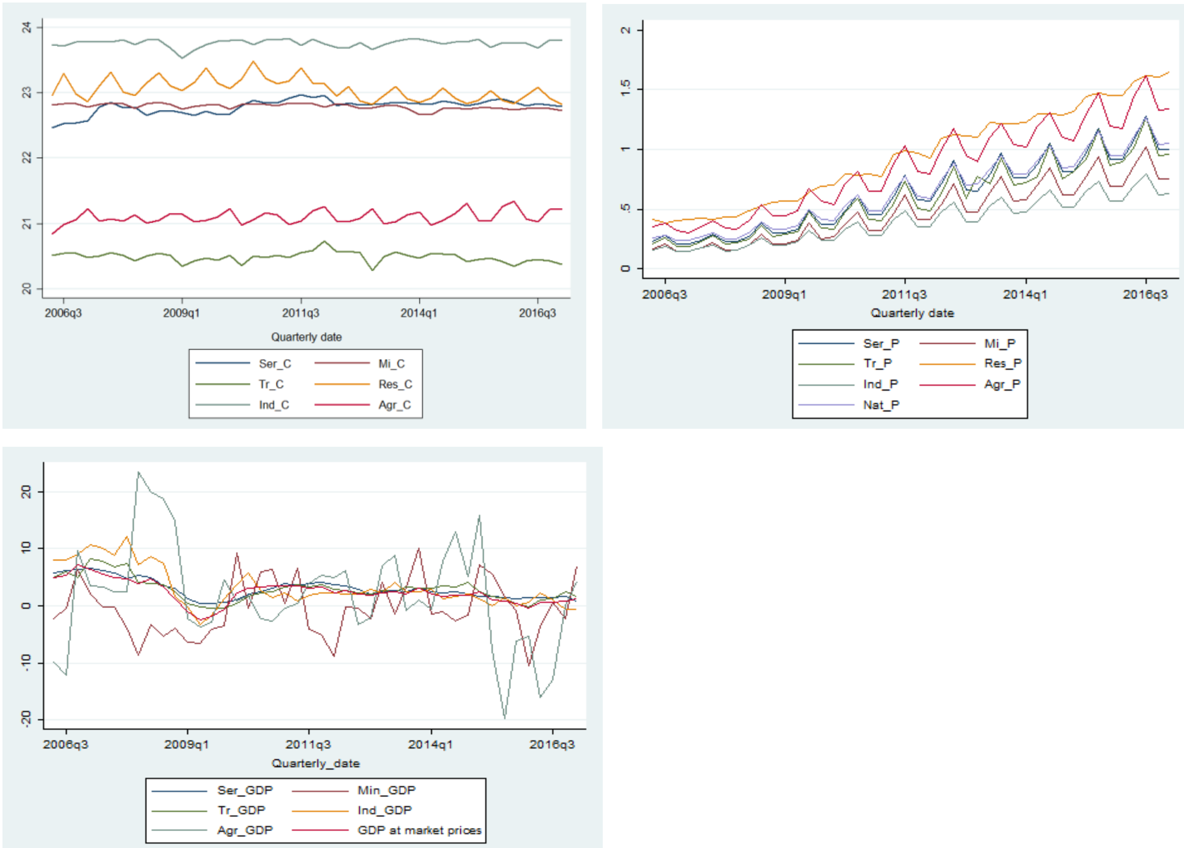
Figure 4: Average electricity price increases – 2008-2020



Source: NERSA

Figure 5 below shows the electricity consumption from 2006 to 2017; the results show that industrial consumed the most electricity throughout the period, followed by the residential sector, while the transportation sector consumed the lowest amount of electricity compared to the other six sectors and followed by the agricultural sector. The results show that there was an escalation of the electricity price from 2006 to 2017 with the residential sector paying the most for electricity followed by agricultural sector. The industrial sector paid the lowest on electricity together with the mining sector. With the economic growth (GDP), the services sector started low in 2006 then had a high escalation between 2007 and a big drop in 2015. Further results show that the industrial sector started on a high level of the economic growth in 2006 and ended with a low level in 2016 The mining sectors showed an inconsistency throughout the ten-year period, however, in 2016 the mining sector had the highest economic growth level.

Figure 5: Electricity consumption (kWh per capita), price (c/kWh) and GDP_G from 2006 to 2017



1.4 Problem definition

From 2019 until 2021, Eskom has been granted approval for a tariff increase that is above inflation rates (NERSA decision: Eskom RCA and MYPD 4 Determination, n.d.). Various stakeholders have raised concerns about the negative implications, including a risk of 90 000 jobs losses in the mining sector alone (www.engineeringnews.co.za). It has been argued that high electricity prices will affect the viability of companies and industries who invested in South Africa on the basis of cheap electricity and who have come to rely on comparative advantage (Inglesi & Blignaut, 2011). Local business and industry associations have argued during the NERSA (2018) hearing that a more thorough understanding of the impact of rising electricity prices on the South African economy at a firm and sector level is required. Furthermore, South Africa is experiencing a low economic growth, therefore it is important for the regulator to be informed of the impact of the increasing electricity prices at sectoral level. As seen from Figure 3, there has been a reduction in consumption of electricity and economic growth since 2013 from (217,022kWh to 214,601kWh in 2017), which supports the claim that tariff increases have an impact on electricity consumption and economic growth.

South Africa's economy contracted an annualised at 3.2% on the quarter ending March 2019. This is an indication that power outages that were experienced in February 2019 had an impact on the economic growth. In addition to the power outages, there was an electricity tariff increase which could add a burden to the current electricity crisis. These factors pose risks to the economy. According to Mazambani (2015) electricity has an input to all sectors of South Africa whether it be directly or indirectly, therefore the increase in electricity prices will have an impact on all the sectors of the economy which then affects the entire economy. South Africa used to enjoy the low electricity prices which had investors investing in South Africa to take advantage of the price competitiveness (J. Cameron & Rossouw, 2012). Therefore, an increase in electricity prices could have an impact on unemployment rate as industries are unable to keep up with the additional burden on the production costs. Therefore, the aim of this paper is to establish the relationship between electricity prices, electricity consumption and economic growth at national and sectoral level. Sector-specific data can address the heterogenous effects of energy conservation policies on different sectors with different energy usage intensities (Lu, 2017). M. E. Bildirici et al., (2012) argue that an increase in electricity consumption has an impact on the improvement in the quality of lives of citizens as well as improvement in the quality of production. Electricity is important as it a pillar for economic and social development, especially for developing countries such as South Africa; thus it is important to policymakers to understand the impact of electricity consumption, electricity prices and economic growth so that informed decisions can be made.

1.5 Research Questions

Hence, this study seeks to answer the following primary research question:

What is the relationship between electricity prices, consumption and economic growth per sector in South Africa over the period of 2006 to 2017?

In addition, the following sub-questions will also be explored:

1. What is the impact of the electricity prices on the electricity consumption (or vice versa)?
2. What is the impact of the electricity prices on the economic growth (or vice versa)?
3. What is the impact of the electricity consumption on the economic growth (or vice versa)?

1.6 Justification of the study

South Africa has experienced a significant increase in electricity prices over the last decade (NERSA decision: Eskom RCA and MYPD 4 Determination, n.d.). Electricity plays a major role in the economic development of many countries by facilitating the development of a wide range of products and services, playing an active role in improving living standards, increasing the productivity and efficiency, as well as encouraging investors and entrepreneurial activities (NDP, 2013).

While there are several studies that examine the relationship between electricity consumption and economic growth (such as Bah & Azam, 2017; Mugano et al., 2017; Inglesi & Blignaut, 2011), there are fewer that include the effects of electricity prices (examples include Roula et al., 2011; Mazambani, 2015; Gonese et al., 2019). According to Shahbaz, Sarwar, Chen, & Malik (2017), developing countries rely on electricity consumption for economic growth and thus electricity prices, rather than oil prices, should be used to study economic growth. In the case of South Africa, many of the studies investigate the relationship between electricity consumption and economic growth at a national and sectoral level (Bah & Azam, 2017; M. E. Bildirici et al., 2012) but to date none have done so including, electricity consumption, electricity prices and economic growth per sector. This study thus seeks to fill this gap.

1.7 Organisation of the study

The structure of the remainder of this dissertation proceeds as follows. Chapter 2 reviews the theoretical and empirical literature devoted to the relationship between electricity consumption, electricity prices and economic growth, and the effect of electricity prices on electricity consumption. Chapter 3 describes the empirical methodology that is used to conduct the research.

Chapter 4 discusses the findings of the analysis, and the study then concludes with a summary conclusion and recommendations for future research in Chapters 5 and 6 respectively.

2. Chapter 2: Literature Review

2.1 Introduction

Developing countries rely on electricity for economic development. According to Kummel (1982), electricity is a factor of output production, which implies that electricity prices affect electricity consumption. This literature review is thus divided into four sections. The first discusses the cross-country and country-specific studies that explore the relationship between electricity consumption and economic growth, the second then explores the relationship between electricity prices and electricity consumption. The third section then focusses on studies devoted to South Africa, and the literature review then concludes with a summary deduction of the key themes.

2.2 Electricity Consumption and Economic Growth

Various country-specific and cross-country studies have investigated the relationship between electricity consumption and economic growth, and generally these can be classified according to four hypotheses: The conservation hypothesis, growth hypothesis, feedback hypothesis and neutrality hypothesis (Asafu-Adjaye, 2000).

2.2.1 Conservation hypothesis

This hypothesis suggests that there is a unidirectional relationship between economic growth and electricity consumption. Mozumder and Marathe (2007) investigated the relationship between electricity consumption and economic growth for Bangladesh using cointegration and vector error correction model (VECM) for the period 1971–1999. The results found that there is a one-way direction relationship from economic growth to electricity consumption, which suggests that economic growth drives electricity consumption. Thus, Mozumder and Marathe concluded that policymakers will need to manage electricity consumption as the economy expands. Golam, Ahamad and Islam (2011) also investigated the relationship between electricity consumption and economic growth for Bangladesh using a VECM for the pre-crisis period from 1971 – 2008. Contrary to Mozumder and Marathe (2007), they found that there is a bi-directional relationship between electricity consumption and economic growth, thus supporting the feedback hypothesis. A possible reason for these contradictory results, however, is the different periods and changing electricity sector. According to Golam, Ahamad and Islam (2011), there is less investment and lack of employment in recent times due to the power crisis that affected economic activity and growth. Using an instrumental variable regression analysis, Tariq et al., (2018) investigate the relationship between economic growth and energy consumption in the four developing Asian countries of Pakistan, India, Bangladesh and Sri Lanka over the time period of 1981 – 2015. The results show that there is a unidirectional relationship from economic growth to energy consumption but GDP, FDI and urbanisation have a positive relationship with energy consumption while trade has a negative correlation with energy consumption. Tariq et al. thus argued that policymakers should ensure that the economy grows faster than electricity consumption, which accords with (Mozumder & Marathe, 2007).

With regard to Africa, Sekantsi and Thamae (2016) investigated the relationship between electricity consumption and economic growth for Lesotho for the period 1972 – 2011 using the ARDL method. The results indicated that there is a unidirectional relationship from economic growth to electricity consumption, which implies that economic growth in Lesotho drives electricity consumption rather than the reverse. Sekantsi and Thamae therefore concluded that energy conservation measures to reduce electricity consumption may not have an impact on economic growth, thus supporting the conservation hypothesis.

2.2.2 Growth hypothesis

In contrast to the conservation hypothesis, the growth hypothesis posits that there is a unidirectional relationship running from electricity consumption to economic growth. Abosedra et al. (2009) investigated the relationship between electricity consumption and economic growth for Lebanon using a bivariate vector regression autoregression model over the period from 1995 – 2005. The results showed that although there is no significant evidence of a long-term relationship between electricity consumption and economic growth, there is unidirectional causality running from electricity consumption to economic growth. Since there is a shortage of electricity supply in Lebanon, Abosedra et al. argued that government should remove regulatory barriers preventing power plant infrastructure development to improve economic growth. Dagher & Yacoubian (2012) also investigated the dynamics of electricity supply in Lebanon using a bivariate framework covering the period from 1980 – 2009 using VECM based on Granger causality test. The empirical results showed that there is a bi-directional relationship between electricity consumption and economic growth which differs from the findings of Abosedra et al. (2009).

Ciarreta and Zarraga (2010) investigated the relationship between electricity consumption and economic growth in 12 European countries using a trivariate VECM estimated by system GMM over the period of 1970 – 2007. The results showed that there is evidence of a significant long-run equilibrium relationship between economic growth, electricity consumption and electricity prices and a negative short-run and strong causality from electricity consumption to economic growth. In addition, it was found that there is bi-directional causality between electricity prices and economic growth and weaker evidence between electricity consumption and electricity prices. According to Ciarreta and Zarraga, the policies of the European Commission should be directed to the efficient use of current capacity, and investment in new generation technologies to support economic growth.

With regard to Africa, Solarin (2011) investigated the relationship between electricity consumption and economic growth for Botswana using Granger causality tests covering the period of 1980 – 2008. The results showed that there is unidirectional causality running from electricity consumption to real GDP. Solarin thus argued that because Botswana is mining based and dependent on South Africa for electricity, the government should invest in power plant infrastructure so that the country can become electricity self-reliant.

More recently, Abokyi et al. (2018) investigated the relationship between electricity consumption and economic growth (industrial growth) in Ghana for the period from 1971–2014, using the ARDL bounds test. The study added trade openness, labour, and capital formation as they influence industrial growth. The results showed that there is a significant and negative long-term relationship between electricity consumption and economic growth. Although Ghana has positive electricity growth, electricity consumption in the industrial sector is found to have a negative impact on manufacturing output. This has resulted in a continued decrease in electricity consumption, which could mean unaffordable electricity prices and the use of obsolete and inefficient equipment and machinery. Abokyi et al. thus suggest that government should invest in electricity generation and strengthen energy efficiency measures to companies.

Inuwa et al. (2019) examined the relationship between electricity consumption and economic growth for Economic Community of West States (ECOWAS) member countries over the period from 2007 – 2016 using Fixed-Effect, Random-Effect, difference and system GMM. The results indicated that there is a unidirectional relationship from electricity consumption to economic growth. Since there is a shortage of power in the region, Inuwa et al. recommended that policymakers should examine alternative electricity generation sources to ensure sufficient and reliable supply of electricity. These two studies demonstrate that policymakers should invest in electricity supply infrastructure.

Samu et al. (2019) examined the relationship between electricity consumption, economic growth, and carbon dioxide emissions for Zimbabwe from 1971 – 2014 based on the Maki cointegration test. The results showed that there is a unidirectional relationship from electricity consumption to economic growth. However, an increase in electricity consumption increases carbon dioxide emissions and this has a negative impact on the environment. Samu et al. thus concluded that the Zimbabwe government should invest in infrastructure; however, should ensure that there is energy diversification by including cleaner and environmentally friendly energy sources. Iyke (2015) investigated the relationship between electricity consumption and economic growth for Nigeria for the period 1971 – 2011 using a trivariate VECM. The results showed that electricity consumption is the driver for economic growth. Iyke thus recommended that policymakers should stimulate electricity demand to enhance economic growth by moderating electricity prices and improving electricity supply.

Thus, in summary, the studies that favour the growth hypothesis suggest that government should invest in cleaner and environmentally friendly energy sources as the demand for electricity grows because any policy that aims at reducing electricity consumption will have an impact on economic growth. Furthermore, government should ensure that regulatory barriers that prevent power plant infrastructure development are minimised while moderating electricity prices.

2.2.3 Feedback hypothesis

In contrast to the conservation and growth hypotheses, the feedback hypothesis argues that a decrease in energy consumption will have an impact on economic growth, which will in turn affect energy demand and thus there will be a bi-directional relationship between electricity consumption and economic growth.

Kasperowicz (2014) examined the causal relationships between electricity consumption and economic growth in Poland from 2000 to 2012 using Granger-causality tests. The results showed that there is a bi-directional relationship between the electricity consumption and economic growth. However, economic growth in Poland is dependent on electricity provision and thus electricity consumption is a limiting factor for economic development. Osman, Gachino, & Hoque (2016) investigated the relationship between electricity consumption and economic growth for the Gulf Corporation Council (GCC) countries, namely Bahrain, Kuwait, Qatar, Oman, Saudi Arabia and the United Arab Emirates (UAE) for the period 1975 – 2012 based on the Panel VAR Granger causality test. The study noted that there is a bi-directional causality between economic growth and electricity consumption in these countries. They thus argued that these countries should invest in additional electricity supply; however due to these countries being oil-producing countries, renewable energy sources should be added on the generation mix to ensure that there is reduction on the greenhouse gas emissions.

Shahbaz et al., (2017) investigated the relationship between electricity consumption, oil price, gross fixed capital formation, population and economic growth of 210 countries over the period 1960 – 2014 using VECM model. The data was categorised by income, OECD and regional level. The empirical evidence is that there is a bi-directional relationship between electricity consumption and GDP, oil price and GDP, fixed capital formation, as well as population and GDP among the countries. Therefore, high economic growth stipulates that industrial development and household living standards leads to increase the electricity consumption. The results demonstrated that developing countries with industrial infrastructure rely more on electricity consumption, as compared to oil prices, for economic growth. Shahbaz et al. thus recommended that electricity policies should be implemented to achieve high economic growth. This is supported by Karanfil & Li, (2015) for 160 countries using a panel data and the same categories namely, income, OECD and regional level for the period 1980 – 2010 adding the degree of electricity dependency and urbanisation as control variables. Karanfil et al., find that in the long run, the results support the feedback hypothesis. However, in the short run there is a unidirectional causality running from economic growth and electricity consumption for North Africa, East Asia and Pacific, and the Middle East which supports the conservation hypothesis except for sub-Saharan Africa, North America and upper-middle-income countries which supports the neutrality hypothesis. According to Karanfil et al., the two variables are highly sensitive to urbanisation, countries' income levels, regional differences and electricity dependency; therefore, while formulating electricity conservation policies, various economic conditions should be considered.

With regard to Africa, Bélaïd and Abderrahmani (2013) examined the relationship between electricity consumption, petroleum prices and economic growth in Algeria over the period of 1971 – 2010 using VECM. The results showed that there is evidence of a short-run and long-run bi-directional causal relationship between electricity consumption and economic growth. Therefore, electricity is a prerequisite for higher GDP growth in Algeria and thus Bélaïd and Abderrahmani concluded that electricity is a limiting factor for the economic growth of Algeria. Algeria is the third largest oil producer in Africa after Nigeria and Libya. Adedokun (2015) examined the relationship between electricity consumption and economic growth for Nigeria – an oil-producing country – using the same methodology VECM and period (1971 to 2011) as the Algeria study. The empirical results showed that there is a long-run bi-directional relationship between electricity consumption and economic growth. In another study by Osman et al. (2016) for GCC oil-producing countries, supported the feedback hypothesis. Adedokun (2015) thus argued that, in accordance with Bélaïd and Abderrahmani (2013) and Osman et al. (2016), policymakers should increase the supply of electricity through hydroelectric power, gas and renewable energy as this will reduce the cost of electricity and further increase economic growth.

Sekantsi and Okot (2016) investigated the relationship between electricity consumption and economic growth for Uganda using a ARDL model covering the period of 1981 – 2013. The empirical results confirmed that there is a long-run bi-directional relationship between electricity consumption and economic growth. Sekantsi and Okot thus recommended that the Ugandan government should develop policies that promote efficient energy use as well ensure that there is electricity infrastructure expansion to meet the increase in demand for electricity to support economic growth.

In summary, the results suggest that governments in countries which adhere to the feedback hypothesis should invest in electricity generation and strengthen energy efficiency measures to companies in order to increase economic growth prospects.

2.2.4 Neutrality hypothesis

Unlike the three previous hypotheses, the neutrality hypothesis argues that electricity consumption has no impact on economic growth and vice versa and thus there should be no causal relationship between electricity consumption and economic growth. Faisal et al. (2018) explored the relationship between electricity consumption, economic growth, urbanisation and trade in Iceland using the Granger test from 1965 – 2013. The ARDL bounds test finds that there is a positive and statistically significant impact of economic growth, trade and urbanisation on electricity consumption for both the long run and short run. However, there is no significant causal relationship between electricity consumption and economic growth; rather, there is a bi-directional causal relationship between urbanisation to electricity consumption, which is to be expected because as urbanisation increases, so will electricity demand. Faisal et al. thus concluded that government should invest in electricity generation to sustain the degree of urbanisation.

With regard to Africa, Tamba et al. (2017) investigated the relationship between electricity consumption and economic growth for Cameroon over the period from 1971 – 2013. The models used for this investigation were Stationary tests, the Johansen cointegration test, the vector autoregressive (VAR) model, and the Granger causality test and they were used as an econometric approach. The results show that there is no causality between electricity consumption and economic growth. Any implementation of energy conservation policies will not have an impact on the economic growth. However Tamba et al, (2017) suggest that the government should put in place policies that will upgrade, produce, distribute and popularise electricity so as to meet the demand and contribute to the economic growth.

Thus, in summary, countries that fall within the neutrality hypothesis are in a difficult position because any implementation of energy conservation policies will not have an impact on economic growth. However, the studies suggest that governments should continue to upgrade, produce, distribute and popularise electricity to meet electricity demand.

2.3 Sectoral output – electricity consumption and economic growth

In addition to the above empirical studies, researchers have also explored the relationship between electricity consumption and economic growth at national level, and on a sectoral basis.

Sankaran, Kumar, and Das, (2019) investigated the relationship on electricity consumption and manufacturing output for ten late industrialised countries for the period 1980 – 2016 using an ARDL bounds testing approach. The results found that the growth hypothesis applies to Morocco, Bangladesh, Bolivia and India while Tunisia supports the conservation hypothesis. The feedback hypothesis was supported by Peru while Sri Lanka, Cameroon and Kenya supported the neutrality hypothesis. Sankaran et al., (2019) argued that the reasons for these disparate results were because the countries vary in terms of their natural resource endowment, population size, technological sophistication, labour markets, institutions, and trade and economic development.

With regard to Asia, Nathan and Liew (2013) examined the relationship between electricity consumption and sectoral output (agriculture, manufacturing, transport and services) in Cambodia using an ARDL Granger test for the period 1980 – 2010. The results showed that there is no long-run relationship (feedback hypothesis) but there is short-run causality running from electricity consumption to all sectors. Nathan and Liew thus concluded that electricity consumption is an important component for sectoral growth in the short run and therefore government should ensure electricity supply stability.

Lu (2017) examined the causality between electricity consumption and economic growth for 17 industries in Taiwan for a period 1998 – 2014 using panel cointegration tests. The results showed evidence of a long-run equilibrium relationship and a bi-directional Granger causality between electricity and economic growth which supports the feedback hypothesis. More specifically, a 1% increase in electricity consumption is found to increase real GDP by 1.72%. Lu thus argued that governments should limit electricity consumption to industries that restrain economic growth while also fostering energy-saving and conservation policies to encourage low electricity intensity production process.

Using the Granger causality test, (Pei, Shaari, & Ahmad, 2016) investigated the relationship between electricity consumption and sectoral output for agriculture, manufacturing and services for Malaysia from 1975 – 2009. Their empirical results revealed that there is a causal relationship running from electricity consumption to agricultural output and no relationship between electricity consumption and the services and manufacturing output. The impact of these results is that an increase in electricity prices or any policy to reduce electricity consumption will not have an effect on the manufacturing and services sectors. Pei et al., (2016) recommended that energy conservation to be implemented should not have a negative impact on the effects on the production of agriculture

Tang & Shahbaz (2013) evaluated the relationship between electricity consumption and real output at national level and at sectoral levels for Pakistan using a Johansen–Juselius cointegration test from 1972 – 2010. The study covered three economic sectors, namely agricultural, manufacturing and services. The results revealed that at national level there is a unidirectional causality from electricity consumption and to real output. The study is contrary to the findings of Abbas & Choudhury (2013) used a Granger causality test for the period 1972 – 2008 which supported the feedback hypothesis for Pakistan. At sectoral level there is a unidirectional causality from electricity consumption to real output in the manufacturing and services sectors and contrary to the findings by Liew, Nathan, & Wong (2012) that supported the conservation hypothesis for both sectors from 1980 – 2007 using the Johansen-Juselius's cointegration approach. However, there is no causal relationship between electricity consumption and real output in the agricultural sector and that is contrary to the Abbas & Choudhury (2013) findings which support the conservation hypothesis and Liew et al., (2012) which support the feedback hypothesis. The results are possibly inconsistent at sectoral level due to the use of different econometric models and study periods. The impact of these results is that agriculture is less dependent on electricity than the manufacturing and services sectors and therefore energy formulation policies should ensure that there is sufficient supply of electricity to boost manufacturing and services sectors. This is supported by Su & Yao (2017) who said that government should be aware that any policy that pro-industrialisation will result in an increase in energy intensity. Su & Yao (2017) argued that the manufacturing sector promotes the use of domestic labour and institutions and is the engine of economic growth.

With regard to Africa, Mawejje and Mawejje (2016) explored the causal relationship between electricity consumption and sectoral output for agriculture, industry, and services in Uganda using a Granger causality test, covering the period from 2005 –2015. Regarding the industrial sector, the results showed that there is long-run causality from electricity consumption to output, while in the services sector there is unidirectional short-run reverse causality running from services to electricity consumption and no causal relationship between electricity consumption and economic growth for the agricultural sector. The results thus indicate that efforts to improve electricity supply will assist in accelerating economic growth in Uganda by facilitating industrial sector growth, as industrial production accounts for 63% of electricity consumption.

Ibrahiem (2018) investigated the relationship between electricity consumption and economic growth at national level and sectoral level in Egypt during the period 1971 – 2013, using a VECM and TYDL. Based on the empirical findings, there is a bi-directional relationship at national level between electricity consumption (feedback hypothesis). At sectoral level, there is a bi-directional relationship between electricity consumption and economic growth for services sector (feedback hypothesis) and a unidirectional relationship running from economic growth to electricity consumption for industrial sector (conservation hypothesis). However, there is no causal relationship between electricity consumption and economic growth for agriculture sector (neutrality hypothesis) and this is agreement with the study by Mawejje & Mawejje (2016). Ibrahiem suggested that at national level, government policies should ensure efficient electricity supply, electricity conservation policies, and environmentally friendly policies that will not affect economic growth negatively. However, for the services and industrial sectors, any energy conservation policies can be implemented but they will not have a significant effect on economic growth.

Thus, in summary, cross-country and country-specific studies indicate that there are significant sectoral differences in terms of the relationship between electricity consumption and output, mainly as a result of differing levels of natural resource endowment, population size, technological sophistication, labour market, government institutions, and economic development.

2.4 Electricity Prices and Electricity Consumption

In this section, studies devoted to the sectoral relationship between electricity prices and electricity consumption are considered. According to Cialani & Mortazavi (2018) it is important to know the consumers' sensitivity to changes in electricity prices for activities such as re-organising production, adjusting controls, planning energy or intermediate product storage systems, and provision of appropriate backup capacities or substitute energy sources.

With regard to developed countries, Wang and Mogi (2017) examined both residential and industrial sector consumption in Japan from 1989 – 2014 using the time varying parameter (TVP) model with the Kalman filter. The results showed that the impact of electricity demand can be explained by a combination of price level changes, external shocks and structural breaks. However, both residential and industrial consumers became less price sensitive after the electricity deregulation and the financial crisis and more sensitive to price after the Fukushima Daiichi crisis. Gautam and Paudel (2018) investigated the demand for electricity in residential, commercial and industrial sectors of the north-eastern United States using panel unit root and cointegration tests over the period from 1997 – 2011. All three sectors were found to be responsive to price elasticity in the long run, but the residential sector was found to be unresponsive in the short run whereas in the commercial and industrial sector, electricity demand is price elastic. According to Gautam and Paudel, the results imply that the electricity pricing mechanism could be an ineffective policy tool for energy conservation. These findings were supported by Cialani & Mortazavi (2018) even though different econometric methodology was used. Cialani and Mortazavi (2018) investigated electricity demand for both residential and industrial consumers and in 29 European countries from 1995 – 2015 using the dynamic partial adjustment model. The findings are that industrial electricity consumption is more price sensitive than residential consumption in both the short and long run which implies that electricity consumption changes more rapidly in the industrial sector than in the residential sector. Furthermore, this is supported by Frondel, Kussel, & Sommer (2019) who established that increasing electricity prices for households by increasing carbon tax may not be an effective means even for low-income households.

(Chindarkar & Goyal, 2019) investigated the price elasticity of residential electricity consumption and disaggregated by state, rural and urban residence, and income categories in India, covering a period from 2005 – 2012 The empirical results were that electricity price increase causes a reduction in electricity consumption and the impact differs significantly among the categories with the rural areas and low income being affected the most. Chindarkar and Goyal thus recommended that tariff setting should be across different income categories.

Campbell (2018) investigated the impact of electricity prices on the electricity consumption for residential, commercial and industrial sectors in Jamaica using the bounds testing approach covering the period of 1970 – 2014. The results were that residential and industrial consumers are responsive to price changes while commercial consumers are less responsive in the long run. This implies that increasing prices as an instrument of rationing electricity supply would be the least distortionary and most cost-effective based on current electricity supply constraints, but the vulnerable low-income households would be negatively affected.

Thus, in summary, these studies show that industrial sector is more price sensitive in the long run and short run, whereas the residential sector is irresponsive in the short run for developed countries. However, the findings are different for developing countries where the residential sector is found to be responsive to price changes, with the rural and low-income areas being affected the most.

2.5 Studies of South Africa

This section reviews the results of empirical studies devoted to South Africa with regard to both the relationship between electricity consumption and economic growth, and the relationship between electricity prices and electricity consumption at national and sectoral level.

With regard to cross-country studies, Bildirici et al., (2012) investigated the relationship between economic growth and electricity consumption for some developed and developing countries using ARDL, covering the period from 1978 to 2010. The empirical results show that the US, China, Canada and Brazil support the growth hypothesis whereas, India, Turkey, South Africa, Japan, UK, France and Italy supports the conservation hypothesis.

Using Granger causality tests, Bayar & Ozel (2014) investigated the relationship between economic growth and electricity consumption for 21 emerging countries, including South Africa, from 1991 – 2011. The results of panel cointegration and a Granger causality test found that electricity consumption has a positive impact on economic growth and that there is bi-directional causality between electricity consumption and economic growth for developing countries. The findings are consistent with Bildirici (2012; Nazlioglu, Kayhan, & Adiguzel (2014) Therefore, developing countries will need to attract FDI to develop the power plant infrastructure needed to promote sustainable growth and development (Ould, 2015). However, in contrast, Bildirici et al., (2012) found that South Africa supported the growth hypothesis in a cross-country study.

Esso (2010) investigated the relationship between electricity consumption and economic growth for seven sub-Saharan African Countries during the period 1970 – 2007 using the threshold cointegration approach. Cote d'Ivoire supports the feedback hypothesis. Congo and Ghana support the growth hypothesis whereas there is no relationship between electricity consumption and economic growth for Cameroon, Kenya, Nigeria and South Africa. The findings for South Africa thus do not accord with Bayar and Ozel (2014) or Bildirici et al. (2012).

Using the Granger causality, Wolde-Rufael (2006) investigated the causal relationships in 17 African countries[1] using Granger causality tests over the period of 1971–2001. The empirical evidence showed that there is a long-run relationship between electricity consumption and economic growth for only 9 countries and Granger causality for 12 countries. For six countries, there is positive unidirectional causality running from real GDP per capita to electricity consumption per capita (Cameroon, Ghana, Senegal, Nigeria, Zambia and Zimbabwe), which accords with the conservation hypothesis; reverse causality for three countries (Benin, the Democratic Republic of the Congo and Tunisia), which accords with the growth hypothesis; bi-directional causality for three countries (Egypt, Gabon and Morocco), which accords with the feedback hypothesis; and no relationship for five countries (Algeria, Congo, Kenya, South Africa, and Sudan), which accords with the neutrality hypothesis. There are four reasons posited for the differing results in Africa. First, non-grid electricity consumption is not considered in the study;

[1] Cameroon, Ghana, Senegal, Nigeria, Zambia, Zimbabwe, Benin, Democratic Republic of Congo, Tunisia, Egypt, Gabon, Morocco, Algeria, Congo, Kenya, Sudan and South Africa

second, inadequate and unreliable electricity supply is a challenge in sub-Saharan countries; third, poverty and access are significant; and lastly, macroeconomic limitations and mismanagement limit financial resources.

In the case of studies devoted to South Africa alone, Odhiambo (2009) investigated the relationship between electricity consumption and economic growth for South Africa which covered the period 1971 to 2006 using the Granger causality test. The empirical evidence found that there is a bi-directional relationship between electricity consumption and economic growth. Odhiambo (2009) argued that firstly this study is different from previous studies due to trivariate causality framework instead of bivariate causality model that may result in omission of variable bias. Secondly, some of the studies have over-relied on the cross-sectional data, which may satisfactorily address the country-specific issues. Lastly, the incorporation of employment as a control variable resulted in a unidirectional causality from employment to economic growth. Odhiambo thus recommended an expansion of electricity infrastructure in order to meet the increasing demand of electricity that is caused by economic growth and rapid industrialisation. This supported by a study by Mugano et al. (2017) that investigated the causal relationships between electricity supply and economic growth for South Africa using the ARDL model over a period from 1985 –2014. Their results indicated that there is a bi-directional causality between electricity supply and economic growth. The impact is that electricity conservation policies would have adverse effects on the economic growth. Therefore Mugano et al., (2017) recommended that government should ensure that there is sufficient, reliable, efficient and clean supply of electricity to meet the demand which supports the recommendation by Odhiambo (2009)

Lin and Wesseh (2014) examined the relationship between electricity consumption and economic growth for South Africa from 1971 –2010 using a bootstrap test algorithm including employment as a control variable. The results indicated that there is a unidirectional causality running from electricity consumption to economic growth and the government should invest more in electricity infrastructure. Dlamini et al. (2015) investigated the causal relationships between electricity consumption and economic growth for South Africa over a period from 1972 – 2009 using a bootstrap rolling Granger non-causality test. The empirical results showed that there is no causality between electricity consumption and economic growth and Dlamini et al. thus concluded that electricity conservation policies and electricity expansion policies will not influence economic growth. The main difference in the study is the inclusion of employment as a control variable (Lin & Wesseh, 2014) which affected the different empirical results.

Mazambani (2015) investigated the impact of electricity prices on economic growth for South Africa using a VECM over the period from 1986 –2013. The results indicated that there is a negative long-run relationship between electricity prices and economic growth, suggesting that an increase in electricity prices will reduce GDP. Mazambani argued that a significant increase in electricity is fatal to businesses that are slightly above break-even point as such businesses will not be able absorb the increase in electricity prices. This could possibly cause a reduction in production, retrenchment of employees and, in extreme cases, businesses closing down. Mazambani thus concluded that government policies should ensure the reduction of the impact of increased electricity prices by introducing "subsidies, gradual price increments, enhanced energy efficiency and demand side management, promoting competition in the electricity supply industry and providing targeted support to vulnerable sectors".

Bah and Azam (2017) investigated the relationship between electricity consumption and economic growth in South Africa from 1971 – 2012. The results of TYDL causality tests found no causal relationships between electricity consumption and economic growth. The implication of these results is that changes to energy-saving policies will not influence economic growth unless government invests in new generation to overcome existing electricity supply constraints. This finding of this study is supported by Dlamini et al., (2015)

On a sectoral level, Roula Inglesi-Lotz & Blignaut (2011) investigated electricity consumption in response to electricity price increases and economic output per sector from 1993 to 2006. The empirical results showed that the industrial sector is the only sector that was highly price elastic while the other sectors were not, namely: Transport, commercial, agriculture and mining. While the output of the industrial and commercial sector was affected by the electricity consumption, this contrasted with the other three sectors whose electricity consumption was not affected by price or by their production. Roula et al., argued that this is due to the low electricity prices during this period of study and it may not be the case given the sharp increases in electricity prices post 2008.

In a review of sectoral electricity elasticities in South Africa before and after the supply crisis of 2008, Blignaut, Inglesi-Lotz, & Weideman, (2015) investigated price elasticity of electricity for various industrial sectors using unit root testing, covering the period from 2002 – 2011. The results showed that there was a statistically insignificant elasticity in the period before the electricity price increases in 2007 whereas there were statistically significant and negative elasticities for 9 of the 11 sectors considered after 2007. This implies that industrial sectors are more sensitive to changes in prices after the sharp increases in 2008, which will disproportionately affect small- and medium-sized enterprises. Blignaut et al. thus concluded that further tariff increases will result in reduced electricity consumption or that consumers will turn to alternative forms of energy.

Mpatane (2015) investigated the impact of electricity supply on the manufacturing sector output for South Africa from 1985 – 2014, using a cointegrated VAR method. The empirical evidence is that there is a positive long-run relationship between manufactured output and electricity supply. According to Mpatane (2015) , policies that will expand the electricity will result in an increase in manufactured output. Therefore, policymakers should formulate and implement policies that promote and expand the electricity sector which could lead to an increase in manufactured output, as this in turn has the further benefit of creating more jobs. Gonese et al. (2019) investigated the impact of prices on sectoral output for South Africa over a period of 1994 – 2015 using panel data analysis. The sectors under review are mining, construction, agriculture, manufacturing, government services, transport, communication, finance and trade. The results show that only two sectors—namely mining and construction do not respond negatively to electricity price changes, therefore electricity prices have a negative impact on sectoral output. This implies that electricity price is a limiting factor to the sectoral production growth therefore electricity prices should be set so as to benefit both the power and economic sector output.

In summary, cross-country and country specific studies that included South Africa found varied support for the neutrality hypothesis, conservation hypothesis, or feedback hypothesis, and thus the relationship between electricity prices, electricity consumption and economic growth remains contentious.

2.6 Conclusion

In conclusion, the relationship between electricity prices and economic growth at national and sectoral level is inconclusive, whether the study is cross-country or country specific. The same applies to the studies relating to South Africa based on the four hypotheses. This may be as result of data selection, variable selection, methodology and many other factors. Studies in favour of the conservation hypothesis state that government should manage electricity consumption as the economy expands. This is supported by a study by Mozumder & Marathe (2007), whereas studies which support the growth hypothesis argue that policy conservation to reduce consumption will have an impact on economic growth (Ciarreta & Zarraga, 2010; Inuwa et al., 2019). However, regarding feedback hypothesis, government is required to invest in electricity generation plants; and energy efficient measures to companies should be put in place as well limit electricity consumption to industries that restrain economic growth when there is a shortage of supply (Osman et al., 2016; Sekantsi & Okot, 2016). The relationship between electricity prices and electricity consumption is also found to vary at a sectoral level.

In terms of South Africa, studies report that the industrial sector has become increasingly electricity price sensitive, and as a result of the impact of the significant tariff increases after 2007, consumption is found to support the feedback and neutrality hypotheses.

3. Chapter 3: Methodology

3.1 Introduction

The purpose of this study is to investigate the relationship between electricity prices, electricity consumption and economic growth per sector of the economy from 2006 to 2017. This chapter thus describes the methodology used to conduct the empirical analysis, starting with the research design, followed by a discussion of the data analysis methods and the empirical models, and concludes with the diagnostic and stability tests used.

3.2 Research Design Strategy

The objective of the study is to empirically determine the relationship between electricity consumption, electricity prices and economic growth and provide reasons and the impact of the results. According to Creswell, (2014) there are the following research designs, qualitative, quantitative and mixed methods. This study is a descriptive because it uses a numerical and mathematical model to analyse and validate data and it deductive because it aims to expand on existing theories taking a top-down approach; as opposed to an of inductive approach, which aims to build new theories, taking a bottom-up approach (Creswell, 2014; Jonker & Pennink, 2010). Therefore this study will follow a deductive, descriptive, quantitative research approach.

3.3 Data Analysis Methods

Based on the literature, there are various methods that can be used to assess the relationship between electricity consumption and economic growth. However, this study uses the autoregressive distributed lag modelling procedure (ARDL) (Pesaran and Shin, 1999; Pesaran et al., 2001) in accordance with Solarin (2011), Abokyi et al. (2018), Faisal et al. (2018) and Marinaş et al. (2018) to test if there is a short- or long-run relationship between electricity consumption and economic growth at national and sector level.

There are three advantages to using the ADRL approach (Zhang et al., 2017). First, the ARDL model can be used irrespective of whether the is variables are I(0), I(1) or both. Second, all variables are assumed to be endogenous. Third, the model can be used for a smaller sample. The study will be conducted using *Stata* software.

3.4 Empirical Process

The following analytical process will be followed to conduct this study

1. Unit root tests will be performed to determine whether the variables are integrated at I(0), I(1) or I(2).
2. The ARDL model will be estimated.
3. Cointegration testing using the ARDL bounds test (Pesaran et al., 2001) is carried out.
4. Diagnostic and stability tests will be performed on the ARDL model to ensure that it correctly specified and stable.

Estimation Methods

Step 1 - Unit root test

This study uses the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1981), and the Phillips-Perron (PP) (Philips & Perron, 1988), as well as the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (Kwiatkowski, Phillips, Schmidt & Shin, 1992) stationarity test to determine whether the variables are integrated at *I(0)* or *I(1)*.

The ADF test assumes that the error terms are statistically independent, and the variance is constant based on the following equation:

$$\Delta \boldsymbol{y_t} = \boldsymbol{c_0} + \boldsymbol{c_1}\,\boldsymbol{t} + \boldsymbol{\delta y_{t-1}} + \boldsymbol{\beta}\sum_{\boldsymbol{t-1}}^{\boldsymbol{n}} \Delta \boldsymbol{y_{t-1}} + \boldsymbol{u_t} \qquad \mathbf{1}$$

where *y* is the variable that will be tested, Δ is the differenced operator, $\boldsymbol{u_t}$is the white noise, $\boldsymbol{c_0}$ is the constant, $\boldsymbol{c_1}$ is the trend, *t* is time subscript, $\{\boldsymbol{\delta}, \boldsymbol{\beta}\}$ are parameters and *n* denote the number of lagged terms.

The disadvantage of the ADF test is its failure to detect structural breaks, which could result in misleading hypothesis testing (Perron, 1986). Therefore, the PP unit root test will also be used:

$$\Delta y_{t-1} = \alpha_0 + \delta y_{t-1} + u_t \quad \mathbf{2}$$

In circumstances where the ADF and PP tests provide conflicting results, the KPSS stationarity test is used to resolve the disparity. The KPSS null hypothesis assumes that variable of interest is stationary and is thus a stationarity test rather than a unit root test. The KPSS (Lagrange Multiplier (LM)) statistic is based on the following equation:

$$LM = \frac{T^{-2} \sum_{t=1}^{T} S_t^2}{s^2(l)} \quad \mathbf{3}$$

where $s^2\,(l)$ is a variance estimator, S_t is a function of $S_{t=} \sum_{t=1}^{T} e_i$, e_i is the least squares residuals.

Step 2 - ARDL Model

After determining which of the factors are level-stationary, and which ones are difference-stationary, the ARDL model can be specified as follows:

$$\Delta e_t = \alpha_0 + \sum_{j=1}^{n} a_{1j} \Delta e_{t-1} + \sum_{j=0}^{n} \alpha_2 \Delta \ln w_{t-1} + \sum_{j=0}^{n} a_3 \Delta \ln x_{t-1} + \sum_{j=0}^{n} \alpha_4 \Delta \ln y_{t-1} + \sum_{j=0}^{n} a_5 \Delta \ln z_{t-1} + \beta_1 e_{t-1} + \beta_2 w_{t-1} + \beta_3 x_{t-1} + \beta_4 y_{t-1} + \beta_5 z_{t-1} + \varepsilon_t$$
4

where ε_t is error term, Δ is the first-difference operator, (e, w, x, y, z) represent long-run forcing variables, $(\alpha_1 - \alpha_5)$ are the long-run parameters, $(\beta_1 - \beta_5)$ are short-run dynamics of the model, α_0 is a drift component, and ε_t is the white noise error term.

Step 3 - Cointegration Test

Cointegration testing is done to determine whether the variables share a common trend (Mungendje, 2017) because evidence of cointegration indicates that there is short- and long-run information among the variables (Nkoro & Uko, 2016). ARDL cointegration testing can be applied irrespective of whether the underlying variables are I(0), I(1) or a combination of both but cannot be applied when the underlying variables are integrated of order I(2) (Nkoro & Uko, 2016). The ARDL bounds testing procedure makes use of the following equation:

$$\Delta \boldsymbol{ln}\, \boldsymbol{e_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\ \boldsymbol{e_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta \ln \boldsymbol{w_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta \ln \boldsymbol{x_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_4}\, \Delta \ln \boldsymbol{y_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_5} \Delta \ln \boldsymbol{z_{t-1}} + \boldsymbol{\lambda ECT_{t-1}} + \boldsymbol{\varepsilon_t} \qquad 5$$

where the error correct term (ECT) is the rate of adjustment towards equilibrium. The null hypothesis is that there is cointegration and thus $\boldsymbol{H_0} : \boldsymbol{\delta_1} = \boldsymbol{\delta_2} = \boldsymbol{\delta_3} = \boldsymbol{\delta_4} = \boldsymbol{\delta_5} = \boldsymbol{\delta_6}$ to be tested against the alternative of $\boldsymbol{H_1} : \boldsymbol{\delta_1} \neq \boldsymbol{\delta_2} \neq \boldsymbol{\delta_3} \neq \boldsymbol{\delta_4} \neq \boldsymbol{\delta_5} \neq \boldsymbol{\delta_6}$. The F test is computed to estimate the lower and upper bounds to establish whether the variables are *I(0)* and *I(1)* in the model. If the F-statistic exceeds the upper level, then the null hypothesis is rejected, implying that there is cointegration among the variables, whereas if the F-statistic is below the lower bound then the null hypothesis cannot be rejected, therefore implying that there is no cointegration. However, if the F-statistic falls within the band, there is indecision and an alternative modelling approach may be more applicable.

Step 4 - Diagnostic and stability tests

It is important to investigate the reliability and validity of the ARDL model. There are several diagnostic and stability tests that can be applied.

According to (Khalid & Khan, 2017), the CUSUM (cumulative sum of recursive residuals) and CUSUMSQ (cumulative sum of squares of recursive residuals) developed by Brown, Durbin and Evans (1975) can be used to test the model for stability. These diagnostic statistics are applied to analyse the stability of short run plus long-run parameter estimates using the following equation:

$$\boldsymbol{CUSUM_t} = \boldsymbol{W_t} = \sum_{r-k+1}^{t} \frac{\boldsymbol{w_r}}{\boldsymbol{s_r}} \qquad 6$$

where W is the recursive residual and s is the standard error of the regression fitted to all T, and t = k+1 …T. If the $\boldsymbol{\beta}$ vector remains constant, then $\boldsymbol{CUSUM_t}$ has zero mean [i.e. E ($\boldsymbol{W_t}$) = 0] and the variance that is proportional to t – k -1 but if the $\boldsymbol{\beta}$ vector does not remain constant then $\boldsymbol{CUSUM_t}$ will incline to diverge from the mean line.

Similarly, the CUSUMSQ statistic is given below:

$$\boldsymbol{CUSUMSQ_t = S_t = \frac{\sum_{r=k+1}^{t} w_r^2}{\sum_{r=k+1}^{T} w_r^2}} \qquad 7$$

where $\boldsymbol{S_t}$ is E($\boldsymbol{S_t}$) = (t-k)/(T-k) which goes from 0 at t =k to one at t=T.

Testing for serial correlation can commonly be conducted using Durbin-Watson (DW) test (Durbin & Watson, 1950), Durbin's h test (Durbin, J, 1970), or the Breusch-Godfrey (1978) LM test. This study uses the Breusch-Godfrey test for serial correlation because it is applicable when a lagged dependent variable is included in the estimations and takes into account higher orders of autocorrelation (Khalid & Khan, 2017).

Similar to the testing of serial correlation, there are many ways of detecting heteroskedasticity such as the Breusch-Pagan LM test (1979), the White's test (1980), the Glesjer LM test (1969), the ARCH test, and the Harvey-Godfrey LM test (Harvey, 1976) (Godfrey, 1978). This study uses the White's (1980) test as it does not assume any earlier determination of heteroscedasticity and does not rely on a normality assumption.

3.5 Empirical Model

This study investigates the relationship between electricity consumption (*EC*), electricity prices (*EP*) and economic growth (*GDP*) at national and sector level (SEC).

In logarithmic form, the basic model can be expressed as follows at national level:

$$\boldsymbol{InGDP_t = \alpha_0 + \alpha_1 \ln EC_t + \alpha_2 \ln EP_t + \ln TRD_t + \ln EMP_t + \ln GFCF_t + u_{t1}} \qquad 8$$

$$InEC_t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln EP_t + \ln TRD_t + \ln EMP_t + \ln GFCF_t + u_{t1} \tag{9}$$

$$InEP_t = \alpha_0 + \alpha_1 \ln EC_t + \alpha_2 \ln GDP_t + \ln TRD_t + \ln EMP_t + \ln GFCF_t + u_{t1} \tag{10}$$

Similarly, the basic model at sectoral level can be expressed as follows:

$$InGDP(SEC)_t = \alpha_0 + \alpha_1 \ln EC(SEC)_t + \alpha_2 \ln EP(SEC)_t + \ln TRD_t + \ln EMP_t + \ln GFCF_t + u_{t1} \tag{11}$$

$$InEC(SEC)_t = \alpha_0 + \alpha_1 \ln GDP(SEC)_t + \alpha_2 \ln EP(SEC)_t + \ln TRD_t + \ln EMP_t + \ln GFCF_t + u_{t1} \tag{12}$$

$$InEP(SEC)_t = \alpha_0 + \alpha_1 \ln EC(SEC)_t + \alpha_2 \ln GDP(SEC)_t + \ln TRD_t + \ln EMP_t + \ln GFCF_t + u_{t1} \tag{13}$$

The ARDL model can thus be stated as follows for national level:

$$\Delta GDP_t = \alpha_0 + \sum_{j=1}^{n} a_{1j} \Delta GDP_{t-1} + \sum_{j=0}^{n} \alpha_2 \Delta ln EC_{t-1} + \sum_{j=0}^{n} a_3 \Delta ln EP_{t-1} + + \sum_{j=0}^{n} \alpha_5 \Delta ln TRD_{t-1} + \sum_{j=0}^{n} a_{6j} \Delta ln EMP_{t-1} + \sum_{j=0}^{n} \alpha_6 \Delta ln GFCF_{t-1} + \beta_1 GDP_{t-1} + \beta_2 EC_{t-1} + \beta_3 EP_{t-1} + \beta_5 TRD_{t-1} + \beta_5 EMP_{t-1} + \beta_6 GFCF_{t-1} + \varepsilon_t \tag{14}$$

$$\Delta EC_t = \alpha_0 + \sum_{j=1}^{n} a_{1j} \Delta EC_{t-1} + \sum_{j=0}^{n} \alpha_2 \Delta ln GDP_{t-1} + + \sum_{j=0}^{n} a_3 \Delta ln EP_{t-1} + \sum_{j=0}^{n} \alpha_5 \Delta ln TRD_{t-1} + \sum_{j=0}^{n} a_{6j} \Delta ln EMP_{t-1} + \sum_{j=0}^{n} \alpha_6 \Delta ln GFCF_{t-1} + \beta_1 GDP_{t-1} + \beta_2 EC_{t-1} + \beta_3 EP_{t-1} + \beta_5 TRD_{t-1} + \beta_5 EMP_{t-1} + \beta_6 GFCF_{t-1} + \varepsilon_t \tag{15}$$

$$\Delta\, \boldsymbol{EP_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\, \boldsymbol{EP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta\, \boldsymbol{ln\, EC_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta\, \boldsymbol{ln\, TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta\, \boldsymbol{ln\, GDP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta\, \boldsymbol{ln\, EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_6}\, \Delta\, \boldsymbol{ln\, GFCF_{t-1}} + \boldsymbol{\beta_1 GDP_{t-1}} + \boldsymbol{\beta_2 EC_{t-1}} + \boldsymbol{\beta_3 EP_{t-1}} + \boldsymbol{\beta_5 TRD_{t-1}} + \boldsymbol{\beta_5 EMP_{t-1}} + \boldsymbol{\beta_6 GFCF_{t-1}} + \boldsymbol{\varepsilon_t} \quad 16$$

The ARDL model for sectoral level is thus as follows:

$$\boldsymbol{GDP(SEC)_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\, \boldsymbol{GDP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta\, \boldsymbol{ln\, EC(SEC)_{t-1}} + + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta\, \boldsymbol{ln\, EP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta\, \boldsymbol{ln\, TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta\, \boldsymbol{ln\, EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta\, \boldsymbol{ln\, GFCF_{t-1}} + \boldsymbol{\beta_1 GDP(SEC)_{t-1}} + \boldsymbol{\beta_2 EC(SEC)_{t-1}} + \boldsymbol{\beta_3 EP(SEC)_{t-1}} + \boldsymbol{\beta_5 TRD_{t-1}} + \boldsymbol{\beta_5 EMP_{t-1}} + \boldsymbol{\beta_6 GFCF_{t-1}} + \boldsymbol{\varepsilon_t} \quad 17$$

$$\Delta\, \boldsymbol{EC(SEC)_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\, \boldsymbol{EC(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta\, \boldsymbol{ln\, GDP(SEC)_{t-1}} + + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta\, \boldsymbol{ln\, EP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta\, \boldsymbol{ln\, TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta\, \boldsymbol{ln\, EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta\, \boldsymbol{ln\, GFCF_{t-1}} + \boldsymbol{\beta_1 GDP(SEC)_{t-1}} + \boldsymbol{\beta_2 EC(SEC)_{t-1}} + \boldsymbol{\beta_3 EP(SEC)_{t-1}} + \boldsymbol{\beta_5 TRD_{t-1}} + \boldsymbol{\beta_5 EMP_{t-1}} + \boldsymbol{\beta_6 GFCF_{t-1}} + \boldsymbol{\varepsilon_t} \quad 18$$

$$\Delta\, \boldsymbol{EP(SEC)_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\, \boldsymbol{EP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta\, \boldsymbol{ln\, EC(SEC)_{t-1}} + + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta\, \boldsymbol{ln\, GDP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta\, \boldsymbol{ln\, TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta\, \boldsymbol{ln\, EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta\, \boldsymbol{ln\, GFCF_{t-1}} + \boldsymbol{\beta_1 GDP(SEC)_{t-1}} + \boldsymbol{\beta_2 EC(SEC)_{t-1}} + \boldsymbol{\beta_3 EP(SEC)_{t-1}} + \boldsymbol{\beta_5 TRD_{t-1}} + \boldsymbol{\beta_5 EMP_{t-1}} + \boldsymbol{\beta_6 GFCF_{t-1}} + \boldsymbol{\varepsilon_t} \quad 19$$

The ARDL bounds testing procedure thus makes use of the following equations at national level:

$$\Delta \boldsymbol{ln\, GDP_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\; \boldsymbol{GDP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta \ln \boldsymbol{EC_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta \ln \boldsymbol{EP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta \ln \boldsymbol{TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta \ln \boldsymbol{EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta \ln \boldsymbol{GFCF_{t-1}} + \boldsymbol{\lambda ECT_{t-1}} + \boldsymbol{\varepsilon_t} \quad 20$$

$$\Delta \boldsymbol{ln}\, \boldsymbol{EC_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\ \boldsymbol{EC_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta \ln \boldsymbol{GDP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta \ln \boldsymbol{EP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta \ln \boldsymbol{TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta \ln \boldsymbol{EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta \ln \boldsymbol{GFCF_{t-1}} + \boldsymbol{\lambda ECT_{t-1}} + \boldsymbol{\varepsilon_t} \quad 21$$

$$\Delta \boldsymbol{ln}\, \boldsymbol{EP_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\ \boldsymbol{EP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta \ln \boldsymbol{EC_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta \ln \boldsymbol{GDP_{t-1}} + + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta \ln \boldsymbol{TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta \ln \boldsymbol{EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta \ln \boldsymbol{GFCF_{t-1}} + \boldsymbol{\lambda ECT_{t-1}} + \boldsymbol{\varepsilon_t} \quad 22$$

The ARDL bounds testing procedure makes use of the following equations at sectoral level:

$$\Delta \boldsymbol{ln}\, \boldsymbol{GDP(SEC)_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\ \boldsymbol{GDP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta \ln \boldsymbol{EC(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta \ln \boldsymbol{EP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta \ln \boldsymbol{TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta \ln \boldsymbol{EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta \ln \boldsymbol{GFCF_{t-1}} + \boldsymbol{\lambda ECT_{t-1}} + \boldsymbol{\varepsilon_t} \quad 23$$

$$\Delta \boldsymbol{ln}\, \boldsymbol{EC(SEC)_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\ \boldsymbol{EC(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta \ln \boldsymbol{GDP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta \ln \boldsymbol{EP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta \ln \boldsymbol{TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta \ln \boldsymbol{EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta \ln \boldsymbol{GFCF_{t-1}} + \boldsymbol{\lambda ECT_{t-1}} + \boldsymbol{\varepsilon_t} \quad 24$$

$$\Delta \boldsymbol{ln}\, \boldsymbol{EP(SEC)_t} = \boldsymbol{\alpha_0} + \sum_{j=1}^{n} \boldsymbol{a_{1j}} \Delta\ \boldsymbol{EP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_2}\, \Delta \ln \boldsymbol{EC(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_3} \Delta \ln \boldsymbol{GDP(SEC)_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta\, \boldsymbol{ln}\, \boldsymbol{TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_5}\, \Delta\, \boldsymbol{ln}\, \boldsymbol{TRD_{t-1}} + \sum_{j=0}^{n} \boldsymbol{a_{6j}} \Delta \ln \boldsymbol{EMP_{t-1}} + \sum_{j=0}^{n} \boldsymbol{\alpha_7}\, \Delta \ln \boldsymbol{GFCF_{t-1}} + \boldsymbol{\lambda ECT_{t-1}} + \boldsymbol{\varepsilon_t} \quad 25$$

4. Chapter 4: Data

This study investigates the relationship between electricity prices, electricity consumption and economic growth per sector of the South African economy from 2006 to 2017 and thus makes use of three dependent factors and four control factors. The sectors that are considered include services (*SER*), industrial (*IND*), transport (*TRA*), mining (*MIN*), agriculture (*AGR*) and residential (*RES*).

4.1 Dependent factors

This study makes use of three dependent factors, consisting of electricity consumption (*Elect_Con*), measured by the kilowatt hour (kWh) per capita in accordance with Ibrahiem (2018); electricity prices (*Elect_Pri*), measured by cents per kilowatt-hours (c/kWh); and economic growth (*GDP_G*), measured by the annual change in gross domestic product. The data for the electricity dependent factors was obtained from Eskom and NERSA while the economic growth data was obtained from the South African Reserve Bank.

4.2 Control factors

In addition to the three dependent factors, the study also makes use of the following four control factors selected in accordance with the literature.

4.2.1 Trade (TRD)

Trade openness is the openness to which a country allows trade with other countries (Ohlan, 2018). Sadikova *et al*. (2017) and Tariq *et al*. (2018). Trade is represented by a sum of real import and exports as a percentage of GDP, which was obtained from the World Bank, and was transformed into natural logarithms. It is anticipated that there will be a positive relationship between trade and electricity consumption because as the economy grows electricity consumption also increases. In contrast, it is expected that high electricity prices will negatively impact trade (Fetahi-Vehapi, Sadiku, & Petkovski, 2015).

4.2.2 Employment level (EMP)

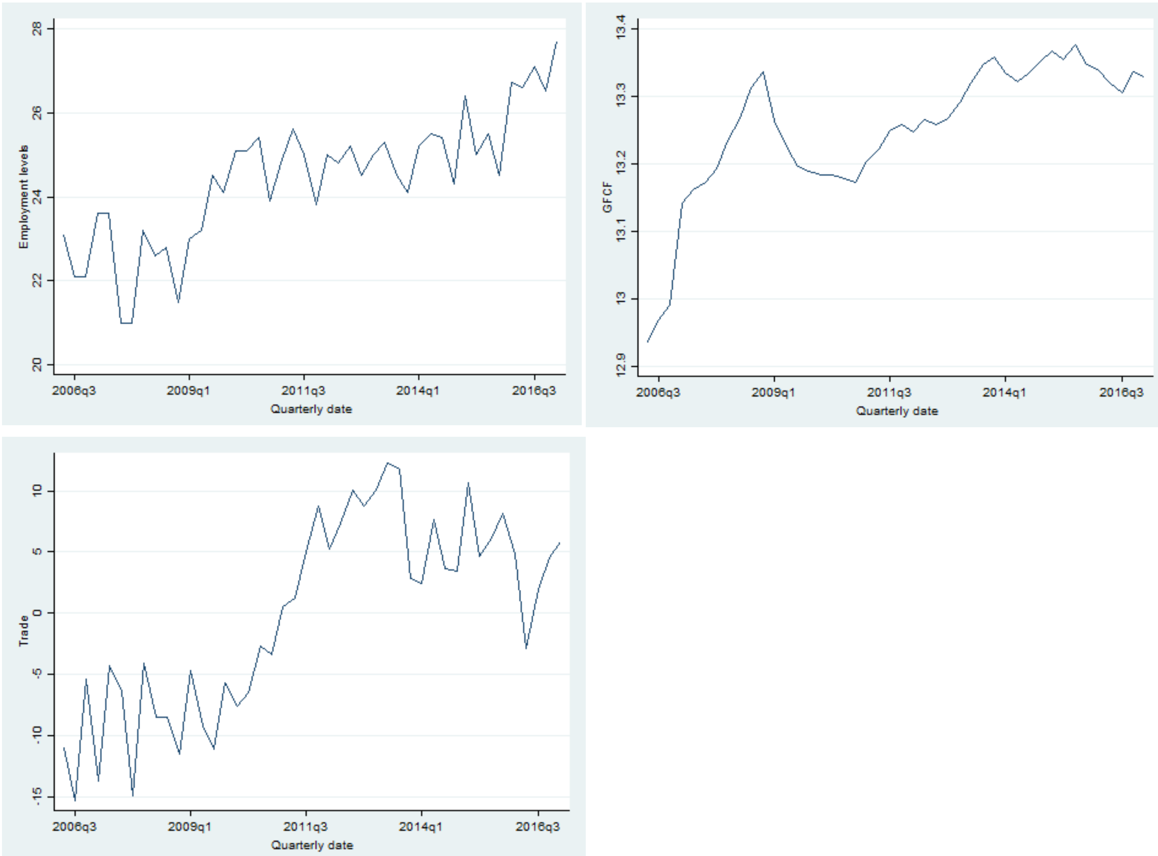
South Africa has a high unemployment rate which puts pressure on government. Unemployment is the labour force that is not part of the production of goods and services and thus a high unemployment rate demonstrates a period of economic decline. Since electricity prices are a production input cost, it is expected that there will be a positive association between high electricity prices and unemployment, and a negative relationship between electricity consumption and unemployment. The unemployment data is obtained from Statistics South Africa.

4.2.3 Gross Fixed Capital Formation (GFCF)

Gross fixed capital formation (*GFCF*) is a determinant of long term economic growth (SARB, 2017). According to Akobeng (2017) an increase in economic growth is usually driven by investment and GFCF is an instrument of reducing poverty. Therefore, it is important to ensure that the electricity prices are low to ensure investor friendly environment as this will increase investment. An increase in investment will have an effect on electricity consumption (Ould, 2015). It is thus anticipated that there will be a positive relationship between GFCF and electricity consumption and economic growth because strong economic conditions influence the growing private sector expansion projects which results in an increase an electricity consumption while high electricity prices should have a negative relationship with GFCF because this could reduce expansion projects. The GFCF data was obtained from Statistics South Africa.

Figure 6 presents the descriptive charts for the variables; the results show that there was an inconsistency of the level of unemployment from 2006 to 2016.

Figure 6: **Control variables**



The results show that there was a significant drop of unemployment level between 2007 and 2008 and an increase in 2015 and 2016, this implies that throughout the years more and more people are slowly getting employed and the unemployment rate is dropping. The Gross Fixed Capital Formation (GFCF) started on low scale in 2006 and had a high capital increase from 2006 to 2009. There was an inconsistency for trade throughout the period however trade had a good quarter during the 2011 to 2014. Towards 2016 there was a big drop and escalated in 2017.

4.3 Sectors

According to Wu and Chen (2016), for developing countries, structural changes and economic development in the national economy cause the primary sector (agriculture) to decrease while the secondary sector (industrial and mining) and tertiary sector (services) increases. This results in a shift of labour from rural areas to urban areas as employment is created by industrial sector.

However employment creation by the industrial sector is determined by the extent to which the manufacturing sector can become labour-intensive rather than capital-intensive (Sen, 2019).

This study thus makes use of the following sectors:

4.3.1 Agriculture Sector

The agriculture sector contributes 2% to the country's GDP. Studies by Ibrahiem (2018) and Mawejje and Mawejje (2016) find that the relationship between electricity consumption and economic growth in the agriculture sector supports the neutrality hypothesis. According to Roula et al. (2011), agriculture electricity consumption in South Africa is not affected by electricity prices.

4.3.2 Industrial Sector

The industrial sector plays a critical role in South Africa as it accounts 35% of GDP. Sadorsky (2013) states that industrialisation increases energy intensity and thus it is expected there will be a negative relationship between industrial output and high electricity prices.

4.3.3 Services Sector

Over the last two decades, South Africa has shifted from promoting the industrial sector to the services sector (Tham, 2017), which now accounts to 26% of the GDP. It is thus expected that the services sector will respond negatively to high electricity prices and electricity consumption would then decrease accordingly (Gonese et al., 2019).

4.3.4 Mining Sector

The mining sector accounts for 8% of the GDP. A country that is resource dependent is vulnerable to volatile economic growth and an erosion of external competitiveness of other tradeable sectors such as agriculture and manufacturing. Gonese et al. (2019) finds that mining sector output was one of the few sectors that were not negatively affected by electricity price changes and thus it is anticipated that electricity consumption will similarly be unaffected.

4.3.5 Transport Sector

The transport sector accounts for 10% of the GDP growth. According to Saidi et al. (2018), transport plays a critical role in the economy as it has a direct or complement to the other factors of production. Therefore, it is expected that the transport sector will be affected by increasing electricity prices which would result in a reduction of electricity consumption (Gonese et al., 2019).

4.3.6 Residential

The residential electricity consumption is likely to be affected by electricity prices as results of the low economic growth and high unemployment rate (Campbell, 2018). It is thus expected that residential consumers will react negatively to an increase in electricity prices which will than reduce electricity consumption (Cialani & Mortazavi, 2018).

5. Chapter 5: Research findings, analysis and discussion

5.1 Introduction

The purpose of this study is to investigate the relationship between electricity prices, electricity consumption and economic growth for national and six selected sectors of the economy from 2006 to 2017. This chapter presents the findings of the study, the sectors that are considered include services (*SER*), industrial (*IND*), transport (*TRA*), mining (*MIN*), agriculture (*AGR*) and residential (*RES*).

5.2 Descriptive statistics

This study makes use of three dependent factors, consisting of electricity consumption (*Elect_Con*), measured by the kilowatt hour (kWh) per capita in accordance with Ibrahiem (2018); electricity prices (*Elect_Pri*), measured by cents per kilowatt-hours (c/kWh); and economic growth (*GDP_G*), measured by the annual change in gross domestic product. The data for the electricity dependent factors was obtained from Eskom and NERSA, while the economic growth data was obtained from the South African Reserve Bank.

The data comprised 44 observations for all three variables across the sectors except the residential sector, which did not have its individual GDP. At national level, the electrical consumption average was 133.99 kWh per capita (SD = 0.274), showing consistency over the period from 2006 to 2017 with minimum consumption of 133.33 kWh per capita and a maximum of 134.63 kWh per capita. The data distribution shows a low Skewness = 0,398 and Kurtosis = 0.375 (Table 1). Electricity prices averaged 0.648 c/kWh (SD = 0.301), with a minimum of 0.237 c/kWh and a maximum of 1.27 c/kWh. The economic growth (*GDP_G*) measured by the annual change in gross domestic product averaged 2.38% (SD = 2.06), with a median 2.25%, and a minimum of -2.58% and maximum of 7.11%.

Within the sectors, the highest average electricity consumption over the period is from the industrial sector with an average of 23.76 kWh per capita, with the lowest from transport sector at 20.49 kWh per capita. For electricity prices, the lowest average prices were from the mining sector for 0.476c/kWh with the highest from residential for 0.952 c/kWh. The data shows a noticeable increase with the lowest national price of 0.24 c/kWh and a highest at 1.27c/kWh with six increases over the period. The highest variation with economic growth varied over the period was encountered in the agricultural sector from -19.70% to 23.48%, with the lowest variation in the services sector from 0.33% to 6.66%.

Table 1: Summary of the descriptive statistics

	Variable	Nat_C	Ser_C	Mi_C	Tr_C	Res_C	Ind_C	Agr_C
Elect_Con	Mean	133,9895	22,7903	22,7932	20,4861	23,0588	23,7630	21,0981
	Median	133,9714	22,8177	22,7991	20,4979	23,0549	23,7801	21,0620
	Std. Deviation	0,27384	0,11293	0,04419	0,07867	0,16823	0,05917	0,10367
	Minimum	133,33	22,47	22,67	20,28	22,82	23,53	20,83
	Maximum	134,63	22,97	22,85	20,73	23,49	23,84	21,34
	Skewness	0,398	-1,087	-0,877	-0,034	0,563	-1,615	0,284
	Kurtosis	0,375	1,063	0,861	1,704	-0,329	4,021	0,046
Elect_Pri	Mean	0,6477	0.6233	0,4764	0,5887	0,9521	0,39944	0,8461
	Median	0,6322	0.6174	0,4748	0,5673	0,9638	0,39608	0,8549
	Std. Deviation	0,30164	0.3051	0,24780	0,30034	0,40592	0,187210	0,37846
	Minimum	0,24	0.21	0,15	0,19	0,38	0,144	0,30
	Maximum	1,27	1.28	1,02	1,27	1,65	0,792	1,62
	Skewness	0,183	0.238	0,309	0,341	0,097	0,257	0,120
	Kurtosis	-1,214	0.357	-1,037	-0,958	-1,329	-1,137	-1,214
GDP_G	Mean	2,3757	2,9358	-0,4427	2,8724		3,2173	1,7556
	Median	2,2496	2,5303	-0,9057	2,6529		2,2000	1,4039
	Std. Deviation	2,06193	1,75795	4,91350	2,09521		3,55888	9,05333
	Minimum	-2,58	0,33	-10,41	-0,43		-3,38	-19,70
	Maximum	7,11	6,66	10,07	8,19		12,07	23,48
	Skewness	-0,084	0,610	0,297	0,708		0,871	0,111
	Kurtosis	0,282	-0,552	-0,397	0,543		0,041	0,513
	Number of observations	44	44	44	44	44	44	44

Table 2 presents the descriptive statistics of the four control variables: Unemployment (EMP), gross fixed capital formation (GFCF) and trade (TRD).). There are 44 observations for all three variables; unemployment level has a mean of 24.43% (SD = 1.555), with the lowest unemployment being 21% and highest being 27.7% over the period. Gross fixed capital formation (GFCF) has a mean of 13.25 (SD = 0.102), a minimum of 12.94 and a maximum of 13.38. Trade has a median of 1.55. The Skewness and Kurtosis range from 1.381 to -0.329 and 1.200 to 2.149, respectively.

Table 2: Descriptive statistics for control variables

	EMP	GFCF	Trade
Mean	24,4295	13,2502	-0,2030
Median	24,6500	13,2647	1,5494
Std. Deviation	1,55467	0,10228	7,92354
Skewness	-0,329	-1,381	-0,244
Kurtosis	-0,033	2,149	-1,103
Minimum	21,00	12,94	-15,32
Maximum	27,70	13,38	12,29
Number of observations	44	44	44

5.3 Correlation matrix of the variables

5.3.1 Correlation for national level

The results of the correlations between the factors on a national basis, presented in Table 3 below, show that electricity consumption has no significant relationship with electricity prices, GDP, or the four control variables (EMP, GFCF, Trade and URB). Electricity prices have a negative and significant relationship with GDP, as well as with the control factors of unemployment level, gross fixed capital formation and trade..

Table 3: Person correlation for the national variables

	1	2	3	4	5	6	7
1. Elect_Con	1.000						
2. Elect_Pri	-0.034	1.000					
3. GDP_G	0.133	-0.471*	1.000				
4. EMP	-0.047	0.816*	-0.434*	1.000			
5. GFCF	0.061	0.713*	-0.552*	0.499*	1.000		
6. Trade	0.091	0.757*	-0.255	0.640*	0.634*	1.000	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

5.3.2 Sectoral correlations

Table 4 below presents the results of the correlation analysis for the six sectors: services, mining, transportation, residential, industrial and agriculture.

5.3.2.1 Services Sector

The services sector correlations show that there is a negative and significant relationship between electricity consumption and economic growth. With regard to the control variables, there is a positive and significant relationship between electricity consumption and unemployment, gross fixed capital formation and trade. Electricity prices similarly have a positive and significant relationship with unemployment, gross fixed capital formation and trade in the services sector. Furthermore, there is a negative and significant relationship between unemployment and economic growth, and a negative and moderately significant relationship between trade and economic growth.

5.3.2.2 Mining Sector

In the mining sector, there is a negative and moderately significant relationship between electricity consumption and electricity prices, and a negative but insignificant relationship between electricity consumption and economic growth. Electricity prices have an insignificant relationship with economic growth while electricity consumption is negatively and moderately significantly correlated with the control factors. Furthermore, electricity prices are significantly correlated with the control factors whereas economic growth has no significant relationship with the control factors.

5.3.2.3 Transportation Sector

In the transport sector, electricity prices have a negative and moderately significant relationship with economic growth whereas the relationship between electricity consumption and electricity prices is insignificant, as are the correlations between electricity consumption and the control factors. In contrast, electricity prices have a positive and significant relationship with the control factors whereas economic growth has a negative and moderately significant correlation with the control factors.

5.3.2.4 Residential

The pairwise correlation analysis of the residential sector shows that electricity consumption and electricity prices are negatively and moderately significantly correlated but electricity consumption and economic growth are insignificantly correlated. Electricity consumption is negatively and moderately significantly correlated with the control factors whereas electricity prices are positively and significantly correlated with the control factors.

5.3.2.5 Industrial Sector

The industrial sector correlations show that electricity prices are positively and significantly correlated with the control factors whereas electricity consumption is positively and significantly correlated with gross fixed capital formation. Economic growth is insignificantly correlated with the control factors.

5.3.2.6 Agricultural Sector

In the agricultural sector, electricity consumption does not have statistically significant relationship with electricity prices nor economic growth whereas electricity prices have a negative and moderately significant relationship with economic growth. With regard to the control factors, electricity consumption has a positive and significant correlation with gross fixed capital formation while electricity prices are positively and significantly correlated with the control factors. In contrast, economic growth is insignificantly correlated with the control factors.

Table 4: Pairwise correlation for the different sectors

Services Sector	1	2	3	4	5	6	7
1. Electrical Cons	1.000						
2. Price	0.6058*	1.000					
3. GDP	-0.3255*	-0.5779*	1.000				
4. Un-Employment Level	0.4706*	0.8011*	-0.6028*	1.000			
5. GFCF	0.6597*	0.6997*	-0.6151	0.499*	1.000		
6. Trade	0.6981*	0.7476*	-0.3728*	0.6396	0.6340	1.000	
Mining Sector	1	2	3	4	5	6	7
1. Electricity Cons	1.000						
2. Electricity Price	-0.4579*	1.000					
3. GDP	-0.0195	0.1600	1.000				
4. Un-Employment Level	-0.5180*	0.7919*	0.2117	1.000			
5. GFCF	-0.4960*	0.6892*	-0.0438	0.4990*	1.000		
6. Trade	-0.3830*	0.7306*	0.1603	0.6396*	0.6340*	1.000	
Transport Sector	1	2	3	4	5	6	7
1. Electricity Cons	1.000						
2. Electricity Price	-0.1946	1.000					
3. GDP	0.3950*	-0.4468*	1.000				
4. Un-Employment Level	-0.2925	0.7966*	-0.5266	1.000			
5. GFCF	-0.2032	0.6981*	-0.4258*	0.4990*	1.000		
6. Trade	0.0195	0.7324*	-0.3024*	0.6396*	0.6340*	1.000	
Residential sector	1	2	3	4	5	6	7
1. Electricity Cons	1.000						
2. Electricity Price	-0.4841*	1.000					
3. GDP	0.0899	-0.4857	1.000				
4. Un-Employment Level	-0.3123*	0.8332*	-0.4344*	1.000			
5. GFCF	-0.3687*	0.7365*	-0.5525*	0.4990*	1.000		
6. Trade	-0.4049*	0.7781*	-0.2551	0.6396*	0.6340*	1.000	
Industrial sector	1	2	3	4	5	6	7
1. Electricity Cons	1.000						
2. Electricity Price	0.0162	1.000					
3. GDP	0.2589	-0.5871*	1.000				
4. Un-Employment Level	0.0841	0.8020*	-0.6081*	1.000			
5. GFCF	0.0213	0.7004*	-0.5525*	0.4990*	1.000		
6. Trade	0.0391	0.7349*	-0.5069	0.6396*	0.6340*	1.000	
Agricultural sector	1	2	3	4	5	6	7
1. Electricity Cons	1.000						
2. Electricity Price	0.1295	1.000					
3. GDP	0.1648	-0.3565*	1.000				
4. Un-Employment Level	0.2646	0.8155*	-0.2718	1.000			
5. GFCF	0.3932*	0.7059*	-0.1167	0.4990*	1.000		
6. Trade	0.2625	0.7317*	-0.0116	0.6396*	0.6340*	1.000	

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

5.4 ARDL Results

This study uses the autoregressive distributed lag modelling procedure (ARDL) (Pesaran and Shin, 1999; Pesaran et al., 2001) to test if there is a short- or long-run relationship between electricity consumption and economic growth at a national and sector-specific level.

5.4.1 Unit root test results

The study first tests for unit roots to ascertain whether the time series is level stationary, I(0), or difference stationary, I(*d*), using the Augmented Dickey-Fuller Test (ADF) (Dickey & Fuller, 1981) and Phillips-Peron (PP) tests. The results of unit root analysis presented in Table 5 show that all the factors are level-stationary, I (0), in the electricity consumption model except for the service sector consumption (*Ser_C*), which is first-difference stationary, I(1). The electricity price factors are stationary at level, I (0) for all sectors based on the result of the trend and intercept. For the GDP, the results are stationary at first difference, I (1).

Among the control variables, the unemployment rate (*Employment*) is stationary at I (0), while gross fixed capital formation (*GFCF*) and trade (*TRD*) are difference stationary at I (1). Hence, the combination of level and first-difference stationarity makes the ARDL cointegration approach the ideal estimation model (Pesaran and Shin, 1999; Harris and Sollis, 2003).

Table 5: Unit root tests with ADF test and Phillips-Peron test

	Variables	ADF Test						Phillip-Peron Test					
		Level			1st Difference			Level			First Difference		
		Intercept only	Intercept and trend	None	Intercept only	Intercept and trend	None	Intercept only	Intercept and trend	None	Intercept only	Intercept and trend	None
Electricity Consumption	Ser_C	-3.240*	-2.948	0.781	-5.688*	-6.068*	-2.451*	-3.250*	-2.901	0.836	-5.632*	-6.119*	-2.116*
	Min_C	-3.328*	-4.594*	-0.311	-6.198*	-6.170*	-2.619*	-3.084*	-4.428*	-0.615	-6.333*	-6.329*	-2.281*
	Trans_C	-4.245*	-4.406*	-0.251	-6.909*	-6.951*	-1.022	-4.249*	-4.425*	-0.419	-7.749*	-11.986*	-2.283*
	Res_C	-3.739*	-4.801*	-0.148	-6.268*	-6.479*	-2.650*	-3.552*	4.690*	-0.358	-7.685*	-10.857*	-2.317*
	Ind_C	-4.358*	-4.326*	0.144	-7.926*	-7.968*	-2.727*	-4.289*	-4.258*	-0.229	-7.939*	-8.037*	-2.415*
	Agr_C	-6.233*	-6.620*	0.413	-7.087*	-7.018*	-2.821*	-6.894*	-8.441*	-1.105	-7.695*	-7.681*	-2.554*
	Nat_C	-4.227*	-4.251*	0.226	-6.739*	-6.893*	-2.703*	-4.182	-4.181*	-0.375	-6.905*	-7.282*	-2.423*
Electricity Price	Ser_P	-1.531	-6.243*	0.094	-6.012*	-6.438*	-2.349*	-0.880	-7.268*	-1.997*	-6.556*	-10.012*	-1.866
	Min_P	-1.765	-6.271*	-0.172	-5.827*	-6.006*	-2.426*	-1.133	-7.624*	-1.413	-6.087*	-6.969*	-2.073*
	Trans_P	-1.765	-7.219*	-0.128	-7.296*	-8.081*	-2.653*	-1.121	-8.655*	-1.510	-7.749*	-11.986*	-2.283*
	Res_P	0.371	-4.631*	3.556*	-6.913*	-6.827*	-2.366*	-1.473	-4.625*	-7.096*	-7.600*	-7.475*	-1.845
	Ind_P	-1.577	-6.097*	0.074	-6.390*	-6.573*	-2.429*	-0.905	-7.481*	-2.010*	-8.027*	-11.021*	-1.914
	Agr_P	-1.279	-5.752*	0.406	-6.441*	-6.806*	-2.430*	-0.632	-6.305*	-2.515*	-7.417*	-11.537*	-1.908
	Nat_P	-1.192	-6.032*	0.481	-6.111*	-6.523*	-2.461*	-0.500	-6.865*	-2.879*	-6.681*	-9.603*	-1.990*
GDP	Ser_GDP	-1.412	-1.530	-1.865	-5.453*	-5.739*	-2.352*	-5.544*	-2.001	-1.712	-5.544*	-5.761*	-2.067*
	Min_GDP	-4.379*	-4.402*	-4.431*	-5.896	-6.583*	-2.287*	-4.485*	-4.492*	-4.535*	-6.544*	-6.655*	-1.909
	Trans_GDP	-1.729	-1.881	-1.404	-6.066*	-6.574*	-2.652*	-1.951	-2.196	-1.465	-6.644*	-6.573*	-2.421*
	Ind_GDP	-1.853	-2.388	-1.849	-6.649*	-6.411*	-2.436	-1.943	-2.608	-1.870	-6.056*	-6.411*	-2.176*
	Agr_GDP	-3.605*	-3.918*	-3.495*	-6.525*	-6.443*	-2.032*	-3.615*	-3.845*	-3.518*	-5.876*	-6.513*	-1.654*
	Nat_GDP	-1.747	-1.830	-1.582	-5.505*	-5.372	-2.226*	-2.090	-2.302	-1.705	-5.457*	-5.378*	-1.965*
Control variables	Employment	-1.930	-4.777*	0.545	-10.150*	-10.458*	-2.729*	-1.255	-4.763*	1.448	-11.18*	-12.925*	-2.349*
	GFCF	-3.631*	-3.048	1.820	-4.365*	-4.650*	-2.184*	-3.411*	-3.052*	1.422	-4.374*	-4.678*	-1.996*
	Trade	-2.253	-3.403	-2.297	-10.014*	-9.903*	-2.863*	-1.948	-3.434	-2.020*	-10.089*	-9.985*	-2.667*

*ADF test: The null hypothesis is that the variable has a unit root. ***, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively indicate that the variable is stationery*

5.4.2 ARDL Bounds cointegration test

The bounds test results are presented in Table 6. This test is conducted to determine whether an ARDL or ECM model is most appropriate (Pesaran, Shin & Smith, 2001). Initially, research determined the optimal lag length by using different criteria before the panel cointegration analysis. As can be seen from Table 6, the optimal lag length selection is 4 lags among the majority of the selection criteria.

Table 6: Lag selection criteria

Lag	LL	LB	df	p	FPE	AIC	HQIC	SBIC
0	-653.802				2.0e+07	33.836	33.928	34.092
1	-576.120	155.360	36	0.000	2.4e+06	31.699	32.341	33.490*
2	-539.479	73.283	36	0.000	2.7e+06	31.666	32.859	34.993
3	-481.850	115.260	36	0.000	1.3e+06	30.556	32.301	35.419
4	-392.670	178.360*	36	0.000	204560*	27.829*	30.125*	34.228

* - *Lag order section by criterion at 5% level*

The bounds test results are presented in Table 7, and this test is conducted to determine whether an ARDL or ECM model is most appropriate (Pesaran, Shin & Smith, 2001). When there is no cointegration, the optimal estimation model is the ARDL for short-run relationships, while an ECM (error correction model) is preferred when there is cointegration. As can be seen in Table 7 below, of the 20 possible models, there are four models that do not exhibit significant cointegration while the other 16 models show significant cointegration. Thus, ARDL models are preferred for the non-cointegrating models while ECM models are applicable for estimating the short-term and long-term cointegrating relationships.

Table 7: F-statistics for cointegration

Sectors	Dependent variables	F-Statistics	Cointegration	Optimal model	
Services	GDP	Fa =7.207, Fc = 3.79	Yes	ECM	Short-term run and long-term run
	Electricity consumption	Fa=25.422, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity Price	Fa=23.350, Fc=3.79	Yes	ECM	Short-term run and long-term run
Mining	GDP	Fa=8.947, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity consumption	Fa=7.719, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity Price	Fa=4.725, Fc=3.79	Yes	ECM	Short-term run and long-term run
Transportation	GDP	Fa=7.568, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity consumption	Fa=5.647, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity Price	Fa=8.141, Fc=3.79	Yes	ECM	Short-term run and long-term run
Residential	Electricity consumption	Fa=1.769, Fc=4.94	No	ARDL	Short-term run
	Electricity Price	Fa=4.986, Fc=4.94	Yes	ECM	Short term run and long-term run
Industrial	GDP	Fa=4.659, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity consumption	Fa=8.244, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity Price	Fa=1.892, Fc=3.79	No	ARDL	Short-term run
Agricultural	GDP	Fa=10.876, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity consumption	Fa=6.811, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity Price	Fa=0.700, Fc=3.79	No	ARDL	Short-term run
National	GDP	Fa=5.363, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity consumption	Fa=5.413, Fc=3.79	Yes	ECM	Short-term run and long-term run
	Electricity Price	Fa=0.876, Fc=3.79	No	ARDL	Short-term run

Fa = F-statistics actual Fc – F-statistics critical

5.5 National Estimation Results

The ARDL and ECM results are presented in Table 8 below. There were three models, electricity prices (Model 1), electricity consumption (Model 2), and economic growth (Model 3). The results of the electricity consumption and GDP growth (Models 2 and 3 respectively) show that there is no statistically significant relationship between electricity consumption and national GDP growth, both in the short term and long term. Hence, this suggests that electricity consumption and GDP both adhere to the neutrality hypothesis in accordance with Faisal et al. (2018). The results further show, however, that in the long run, electricity prices are statistically significant in the economic growth model (Model 3) but the negative coefficient implies that electricity prices are elastic, which accords with Mazambani (2015).

In contrast, the results show that electricity consumption has an insignificant relationship with the electricity prices in the short run, while electricity prices have an in significant relationship with electricity consumption both in the short- and long-run. This suggests that balancing electricity demand and supply should focus on the efficient use of current capacity, and investment in new generation technologies to support economic growth as increases in electricity prices negatively affects the country’s economy (Ciarreta & Zarraga, 2010). With regard to the control factors, the results show that there is a positive and statistically significant relationship between employment and national GDP, compared to a negative and weakly significant relationship between trade and national GDP.

Table 8: **The ARDL and EC models for estimates of relationship for national level**

	Dependent variables_ National			
	Variables	Electricity Price (Model 1)	Electricity Consumption (Model 2)	GDP_G (Model 3)
LR	ΔNat_C			0.172(1.62)
	Nat_P			-36.33(-5.18)***
	ΔNat_P		1.262(1.45)	-0.203(0.77)
	ΔNat_GDP		0.229 (1.82)	
	Emp		-4.901(-2.74)*	8.174(4.80)***
	ΔGFCF		-0.071(-0.49)	-0.035(-0.44)
	ΔTrade			-0.624(-2.82)*
SR	ΔNat_C	0.2205 (1.77)		
	Nat_P			-100.2(-2.23)*
	ΔNat_P		-0.485(-2.04)	
	Nat_GDP			
	ΔNat_GDP	-0.2277 (-2.66)*		
	Emp	2.8617(2.37)*	4.098(1.67)	5.187(1.91)
	ΔEmp			
	GFCF	0.1361(1.38)		
	ΔTrade			0.314(1.87)
	_cons	-30.67(-1.10)	118.16(2.49)*	-266.0(-3.17)**

****, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively*

Electricity price: ARDL: F-statistics= 9.82*** Electricity consumption and GDP: ECM

5.6 Sectoral Estimation Results

The results of the sectoral estimations are discussed separately below.

5.6.1 Services sector

The results of the services sector estimations are presented in Table 9 below. The electricity consumption estimations (Model 4) shows that there is a positive but weakly significant relationship between electricity prices and electricity consumption in the short run in the services sector. This result therefore suggests that the services sector will respond negatively to high electricity prices and thus electricity consumption would decrease accordingly. There is also a moderately significant relationship between GDP growth and electricity consumption, which indicates that economic growth in the services sector drives electricity consumption rather than the reverse, which accords with Wolde-Rufael (2006) and thus adheres to the conservative hypothesis. This finding reiterates the need for South Africa to ensure that there is efficient electricity supply to support the economic growth of the services sector (Ibrahiem, 2018).

The electricity price estimations (Model 5) shows that neither electricity consumption nor GDP have a significant effect on the electricity prices for the services sector. According to Blignaut et al. (2015), the services sector is not an intensive electricity user and therefore any electricity price change will not affect the electricity consumption nor GDP. This suggests that in the services sector, the electricity pricing mechanism may be an ineffective policy tool for promoting energy conservation, as electricity consumption is not affected by changes to electricity prices (Gautam & Paudel, 2018).

The results of the GDP growth estimations (Model 6), in contrast, find that there is a moderately significant but negative relationship with GDP in the long run for services sector, which means that electricity prices are elastic and negatively impact services sector GDP. Finally, employment is found to have a significant relationship with electricity prices and GDP. These results thus suggests that growth in the services sector is dependent on moderate electricity prices and the improvement of electricity supply as the resultant electricity consumption drives for economic growth in the sector (Iyke, 2015).

Table 9: The ARDL and EC models for estimates of relationship for service sector

	Dependent variables_ Service			
	Variables	Electricity Consumption (Model 4)	Electricity Price (Model 5)	GDP_G (Model 6)
LR	ΔSer_C		0.096 (0.32)	0.424 (1.54)
	Ser_P	-1.576(-0.07)		-31.347 (-3.31)**
	ΔSer_GDP	-0.552(-2.08)	0.739 (0.29)	
	Emp	-5.483(-0.92)	1.017 (0.43)	5.969 (2.66)*
	ΔGFCF	-0.547(-1.61)	0.061 (0.38)	-0.048 (-0.24)
	ΔTrade	0.523(1.67)	-0.052 (-0.38)	0.019 (0.12)
SR	Ser_C			
	ΔSer_C			-0.111 (-1.25)
	Ser_P	118.23(2.85)*		
	ΔSer_P			
	Ser_GDP	0.490(4.52)**	-0.000(-1.38)	
	ΔSer_GDP			
	Emp	3.18(1.87)	-0.011(-1.76)	
	ΔGFCF	0.303(1.74)	-0.001 (-1.97)	0.291 (1.76)
	Trade			
	ΔTrade	-0.300(-2.54)*	0.001 (1.63)	
	_cons	169.53(1.16)	-0.814(-1.90)	-116.40(-2.01)

****, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively*

Electricity consumption, Electricity price and GDP: ECM

5.6.2 Mining sector

All three estimation models for the mining sector were conducted using Error Correction Models (ECM) as the data exhibited cointegration. The results of the electricity consumption (Model 7), electricity prices (Model 8), and GDP growth (Model 9) estimations in the mining sector are presented in Table 10 below.

The electricity consumption estimations (Model 7) show that electricity consumption is negatively associated with electricity prices in the mining sector, which suggests that an increase in electricity prices decreases electricity consumption in the mining sector, possibly because mining companies will have to turn to alternative forms of energy (Blignaut et al., 2015).

The electricity price estimation (Model 8) shows that GDP has a negative and significant influence on electricity prices in the long run but the short-run effect is positive and significant. Of the control factors, only employment is significant and has a positive relationship with electricity prices. Thus, growth in employment levels in the mining sector has a positive influence on the electricity prices in the long run.

The mining sector is an intensive electricity user but contributes significantly to the country's economic growth, Model 7 and 9 therefore indicate that an increase in electricity prices will increase production costs, which in turn will affect economic growth (Blignaut et al., 2015).

The GDP model (Model 9) finds that there is no significant relationship between GDP and both electricity consumption and electricity prices in the long run in the mining sector. However, electricity prices show evidence of a negative elasticity in the short run, which suggests that an increase in electricity prices in the mining sector has a negative impact on the GDP. Thus, electricity price is a hindrance on mining production costs in South Africa and the government should thus set electricity prices to benefit both the power and the economic sector output (Gonese et al., 2019). In contrast, GDP does not have a statistically significant impact on electricity consumption, and thus both GDP and electricity consumption in the mining sector adhere to the neutrality hypothesis.

Table 10: The EC models for estimates of relationship for mining sector

	Dependent variables_ Mining			
	Variables	Electricity Consumption (Model 7)	Electricity Price (Model 8)	GDP_G (Model 9)
LR	ΔMin_C		0.082(0.58)	0.063 (0.32)
	Min_P	-14.323 (-2.35)*		-29.143 (-1.84)
	Min_GDP	-0.437 (-1.54)		
	ΔMin_GDP		-0.514(-3.57)**	
	Emp	2.377 (2.01)	2.970(5.83)***	8.247 (2.04)
	ΔGFCF	0.0123 (0.17)	-0.038 (-0.71)	0.0942 (0.41)
	ΔTrade	-0.899 (-4.24)***	-0.2670 (-1.86)	-0.449 (-2.11)
SR	Min_C			
	ΔMin_C		-0.192(1.47)	0.110 (0.99)
	Min_P	-126.883 (-1.95)		-119.148 (-2.36)*
	ΔMin_GDP	0.533 (1.74)	0.385(4.17)**	
	Emp		-1.765(0.98)	-2.748 (-2.18)8
	ΔGFCF		-1.0122(1.14)	0.273 (2.48)**
	ΔTrade	0.427 (3.62)**	0.161(1.24)	-0.084 (-1.09)
	_cons	-9.116(-0.21)	-82.46(-2.28)*	-199.54(-2.56)**

****, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively*

Electricity consumption, Electricity price and GDP: ECM

5.6.3 Transportation sector

The results of the electricity consumption (Model 10), electricity prices (Model 11), and GDP growth (Model 12) estimations in the transportation sector are presented in Table 11 below. The electricity consumption model (Model 10) shows that electricity prices have a negative elastic effect on electricity consumption. Furthermore, the model shows that GDP has a positive weakly significant impact on the electricity consumption in the short run, but a negative and weakly significant relationship with electricity consumption in the long run. This result is not too surprising, however, as the transportations sector consumes the lowest amount of electricity. The results also show that there is a relationship between GDP and the electricity consumption both in the short- and long-run, which suggest that the factors adhere to the conservative hypothesis. Among the control factors, employment is found to have a negative and weakly statistically significant relationship with electricity consumption in the short run, but a positive and weakly significant relationship with electricity consumption in the long run. These findings thus imply that the transport sector will not be significantly impacted by any energy conservation policies (Sekantsi & Thamae, 2016).

With regard to the electricity price estimations (Model 11), all of the factors are found to be insignificant with the exception of employment, which is highly significant and positive in the short-run. Hence, this suggests that electricity prices are not a limiting factor for the transportation sector (Gonese et al., 2019). The GDP estimations (Model 12) further show that both electricity consumption and electricity prices have no statistically significant relationship with GDP in both the short- and long-run in the transportation sector. Hence, this finding suggests that the relationship between electricity consumption and economic growth adheres to the neutrality hypothesis. In accordance with Tamba et al. (2017), this implies that energy conservation policies will not have a significant impact on economic growth in the transportation sector. These results are not unexpected because the transport sector is low energy intensive and is thus likely to adhere to the neutrality hypothesis.

Table 11: The EC models for estimates of relationship for transportation sector

	Dependent variables_ Transportation			
	Variables	Electricity Consumption (Model 10)	Electricity Price (Model 11)	GDP_G (Model 12)
LR	ΔTran_C		-0.013(-1.14)	0.377 (1.39)
	Tran_P	-1.424(-3.38)**		5.059 (0.18)
	ΔTran_GDP	-0.500 (-2.26)*	-0.012(-1.20)	
	Emp	3.209 (2.32)*	0.227(4.52)***	-0.177 (-0.25)
	ΔGFCF	0.162 (1.00)	0.001(0.68)	-0.836 (-1.69)
	ΔTrade	0.646(2.18)	-0.011(-0.80)	-0.947 (-1.19)
SR	Tran_C			
	ΔTran_C		0.004(1.84)	
	Tran_P	0.516 (1.53)		-37.604 (-1.82)
	ΔTran_GDP	0.553(2.63)*	0.002(0.91)	
	Emp	-6.060 (-2.04)	0.039(1.14)	8.247 (2.49)*
	ΔGFCF	0.385 (-1.88)	-0.002(-0.82)	0.523 (2.42)*
	ΔTrade	-0.473 (-2.34)*	0.001(0.62)	-0.204 (-1.05)
	_cons	24.810(0.43)	-1.58(-1.07)	59.91(0.55)

****, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively*

Electricity consumption, Electricity price and GDP: ECM

5.6.4 Residential sector

The results of the electricity consumption (Model 13) and electricity prices (Model 14) estimations in the residential sector are presented in Table 12 below. The results show that there are no significant relationships between the factors in either model. This is not unexpected as previous studies have similarly found that the residential sector tends to be unresponsive to electricity consumption and pricing (Chindarkar & Goyal, 2019). According to (Bohlmann & Inglesi-lotz (2018), South Africa has an 87% electrification rate but more than 70% of low-income households use other energy sources such as candles, firewood, paraffin and coal. Consequently, it is not unexpected that there is an insignificant association between the electricity factors in the residential sector.

Table 12: **The EC models for estimates of relationship for residential**

Dependent variables_ Residential			
	Variables	Electricity Consumption (Model 13)	Electricity Price (Model 14)
LR	Res_C		
	ΔRes_C		0.000 (0.03)
	Emp		0.548 (2.39)*
	ΔGFCF		0.001(0.12)
	ΔTrade		0.004 (0.37)
SR	Res_C		
	ΔRes_C	-0.079 (-0.59)	
	Res_P	-9.79 (-1.79)	
	Emp		-0.149 (-1.68)
	ΔGFCF	-0.011 (-0.15)	
	ΔTrade	0.031 (0.46)	
	_cons	-9.81(-0.32)	-0.539(-2.68)*

****, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively*

Electricity price: ECM F-statistics= 26.21*** Electricity consumption: ARDL

5.6.5 Industrial sector

The results of the industrial sector estimations are presented in Table 13 below. The electricity consumption estimations (Model 15) show that GDP has a positive and weakly significant relationship with electricity consumption in the short run but has no significant relationship with electricity consumption in the long run. On the other hand, electricity consumption has no significant impact on the GDP in both the short- or the long-run, and thus adheres to the conservational hypothesis. Among the control factors, employment, gross fixed capital formation, and trade are found to have significant long-term relationships with electricity consumption and electricity prices in the long run; whereas GDP and unemployment are positively associated with electricity consumption and electricity prices in the short run. The industrial sector is among the most extensive electricity users in the country but like mining, also contributes significantly to the country's GDP (Blignaut et al., 2015). This implies that industrial sector growth is dependent on electricity consumption and pricing and thus government should formulate policies that ensure that there is sufficient supply of electricity to stimulate the energy intensive industrial sector (Su & Yao, 2017; Tang & Shahbaz, 2013; Mawejje & Mawejje, 2016).

The electricity price estimations (Model 16), show that electricity consumption has a positive and significant relationship with electricity prices in the industrial sector, which suggests that higher electricity demand drives up electricity prices, which is likely an outcome of the country's user-pays model (www.nersa.co.za). This implies that an increase in electricity prices could be an effective policy tool for energy conservation (Gautam & Paudel, 2018).

Model 17 shows that electricity prices have a negative elasticity on the GDP in the long run, which accords with Sadorsky (2013). The GDP growth estimations (Model 17) also show that gross fixed capital formation has a positive but weakly significant relationship with electricity prices. This is possibly because increases in electricity could result in reduced production competitiveness which negatively impacts GDP by supply and capacity contraints (Bildirici et al., (2012).

Table 13: The ARDL and EC models for estimates of relationship for industrial sector

		Dependent variables_ Industrial		
		Electricity Consumption (Model 15)	Electricity Price (Model 16)	GDP_G (Model 17)
LR	Ind_C			0.371(1.51)
	Ind_P	-48.351 (-3.20)**		-22.983(-2.36)*
	Ind_GDP	-0.378 (-1.49)		
	Emp	4.291 (2.46)*		1.2852(0.97)
	ΔGFCF	-0.258 (-3.27)**		-0.124(-0.91)
	ΔTrade	-0.713(-3.03)**		0.0545(0.16)
SR	Ind_C			
	ΔInd_C		0.002(3.63)**	-0.332(-1.69)
	Ind_P	64.541(1.03)	0.156(1.46)	
	ΔInd_GDP	0.451(2.85)*	0.000(1.00)	
	Emp	-7.838(-3.03)**		
	ΔGFCF		0.001(1.51)	0.428(2.34)*
	Trade			
	ΔTrade	-0.181(-1.18)	-0.000(-0.49)	
	_cons	-63.69	-0.435**	-11.58

****, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively*

Electricity price: ARDL: F-statistics= 214.64*** Electricity consumption and GDP: ECM

5.6.6 Agricultural sector

The ARDL and the EC results of the electricity consumption (Model 18), electricity prices (Model 19), and GDP growth (Model 20) estimations in the agricultural sector are presented in Table 14 below. The electricity consumption estimations (Model 18) shows that there is no significant relationship between electricity consumption and electricity prices, nor with GDP.

Hence, these factors adhere to the neutrality hypothesis, which accords with Ibrahiem (2018) and Mawejje and Mawejje (2016). A significant portion of the country's agriculture sector either does not use much electricity or energy needs are met by self-generation or alternative energy sources (Deloitte, 2013) and thus this result it is not unexpected.

The electricity price estimations (Model 19) similarly find that there is no significant relationship between electricity consumption and electricity prices in the short run, which accords with Roula et al. (2011), and once again is an outcome of the agriculture sector's low energy intensity (ww.eskom.co.za). However, there is a positive and moderately significant relationship between electricity prices and the GDP in the agricultural sector, which suggests that economic growth leads to an increase in the electricity prices in the agricultural sector. This is contrary to Gonese et al., (2019) and suggests that electricity prices are not a limiting factor in agricultural production, possibly because the agricultural sector is more labour intensive than electricity intensive. With regard to the GDP growth estimations (Model 20), electricity consumption is found to have a positive and significant relationship with agricultural sector economic growth in the short run, which accords with the growth hypothesis.

Table 14: The ARDL and EC models for estimates of relationship for agricultural sector

		Dependent variables_ Agriculture		
		Electricity Consumption (Model 18)	Electricity Price (Model 19)	GDP_G (Model 20)
LR	ΔAgri_C			-0.765(-1.71)
	Agri_P	12.991(1.57)		-6.434(-0.64)
	Agr_GDP	0.350(1.22)		
	Emp	-2.661(-0.94)		1.7698(0.55)
	ΔGFCF	-0.5995(-2.15)*		0.304(1.04)
	ΔTrade	-0.209(-1.44)		0.347(2.18)*
SR	Agr_C		-0.159(-1.21)	
	ΔAgr_C			0.381(3.24)**
	Agr_P	35.466(1.41)	0.479(4.24)***	-27.191(-1.18)
	Agri_GDP	0.4041(1.49)	0.003(3.02)**	
	Emp	4.064(1.29)	0.031(3.19)**	
	ΔGFCF	0.442(2.28)*	0.001(0.76)	-0.187(-2.26)*
	_cons	147.30	1.602(0.57)	-16.84(-0.35)

****, ** and * represent a significance at the 1%, 5% and 10% critical level, respectively*

Electricity price: ARDL: F-statistics= 335.86*** Electricity consumption and GDP: ECM

5.7 Model diagnostics and stability

The diagnostic tests for all the models are presented in Table 15, and show that there is no significant serial correlation, heteroscedasticity, or non-normality of the residuals. The cumulative sum of the recursive residuals (CUSUM) further show that three models (electricity price, electricity consumption and GDP) are all stable[2].

[2] The CUSUM results are presented in Appendix A.

Table 15: Diagnostic test results

Sectors	Dependent variables	Durbin-Watson	Breusch-Godfrey LM test	White's test	Heteroskedasticity (IM Test)	Skewness (IM Test)	Kurtosis (IM Test)
National	GDP	2,23	2.797	41	41	18.93	0.33
	Electricity consumption	1.95	7.033	39	39	13.09	2.32
	Electricity Price	2.09	1.186	41	41	9.43	2.98
Services	GDP	2.07	4.18	41	41	8.95	0.24
	Electricity consumption	2.15	10.88	39	39	23.93	1.14
	Electricity Price	1.62	8.71	39	39	24.35	1.07
Mining	GDP	1.65	9.34	39	39	32.61	0.27
	Electricity consumption	2.16	13.57	39	39	15.06	3.69
	Electricity Price	2.317	5.503	39	39	23.57	2.72
Transportation	GDP	1.99	5.73	39	39	18.15	0.42
	Electricity consumption	2.37	4.582	39	39	26.45	1.08
	Electricity Price	2.149	6.271	40	40	20.17	0.84
Residential	Electricity consumption	2.13	7.28	39	39	9.72	0.92
	Electricity Price	1.51	6.08	40	40	8.79	0.27
Industrial	GDP	2.08	3.68	39	39	14.71	0.39
	Electricity consumption	1.87	3.78	39	39	26.42	0.14
	Electricity Price	1.71	3.85	39	39	21.01	2.02
Agricultural	GDP	1.75	5.57	39	39	22.85	0.01
	Electricity consumption	2.38	8.79	39	39	24.87	0.99
	Electricity Price	1.91	6.057	40	40	17.63	1.80

IM Test - Cameron & Trivedi's decomposition IM Test * - $p < .05$

6. Chapter 6: Conclusion and recommendation

6.1 Introduction

This chapter provides a summary of the research findings and conclusions arising from the research analysis, and then concludes with policy implications and recommendations for further study.

South Africa has been faced with major electricity price increases over the past few years. Thus, this study investigated the relationships between electricity prices, electricity consumption and economic growth at national and sectoral level for the period April 2006 to March 2017.

6.2 Conclusion

Having conducted the analysis, the section below seeks to answer the research questions posed in Section 1.4.

6.2.1 What is the relationship between electricity prices, consumption and economic growth per sector in South Africa over the period of 2006 to 2017?

With regard to electricity consumption, at national and in the mining and residential sectors, the relationship between electricity consumption and GDP is insignificant and thus adheres to the neutrality hypothesis. In contrast, in the services, transportation and industrial sectors there is a positive relationship between GDP and electricity consumption, which adheres to the conservative hypothesis. Lastly, the agricultural sector has a positive relationship between electricity consumption and economic growth in the short run, and thus adheres to the growth hypothesis.

The results for the relationship between electricity prices and electricity consumption show in the that national, services sector, transport sector, residential and agricultural sector electricity consumption has an insignificant relationship with the electricity prices. However, the mining electricity consumption is negatively associated with electricity prices and the industrial sector electricity consumption has a positive and significant relationship with electricity prices.

With regard to the relationship between electricity prices and GDP, the results find that there is an elastic association in the national, services, mining, and industrial sectors with a negative impact on the GDP in the long run. In contrast, the relationship between electricity prices and GDP in the transport and residential sectors is insignificant.

6.2.2 What is the impact of the electricity prices on the electricity consumption (or vice versa)?

The results find that electricity consumption has an insignificant relationship with the electricity prices on a national basis, and in the services, transport, residential and agricultural sectors. The transport, agricultural and services sector are low energy use sectors while much of the residential sector is still reliant on cheap alternative energy sources. Hence, it is not unexpected that these sectors will exhibit an insignificant relationship between electricity prices and electricity consumption. In contrast, in the mining sector, increases in electricity prices decrease electricity consumption whereas in the industrial sector, consumption has a positive and significant relationship with electricity prices.

6.2.3 What is the impact of the electricity prices on the economic growth (or vice versa)?

The impact of the electricity prices is found to be elastic on a national level and in the services, mining and industrial sectors, and thus electricity prices are a hinderance to economic growth in South Africa. This can be explained by the services, mining and industrial sector significant contribution to the country's GDP. In contrast, electricity prices are found to insignificantly affect the agricultural and residential sectors. This is not unexpected as the agricultural sector is a low energy intensive sector while the country's residential sector is reliant on cheap easy-burning energy sources such as paraffin and coal.

6.2.4 What is the impact of the electricity consumption on the economic growth (or vice versa)?

Electricity consumption has an insignificant relationship with GDP in the mining and residential sectors and thus adheres to the neutrality hypothesis. In contrast, the relationship is positive in the services, transportation and industrial sectors and thus adheres to the conservative hypothesis. The agricultural sector also has a positive relationship but only in the short run, and thus adheres to the growth hypothesis.

6.3 Policy recommendations

Based on the findings discussed above, there are three policy recommendations:

i. With regard to the negative impact of electricity price increases on GDP for the services, mining and industrial sector, it is recommended that policymakers should ensure that subsidies and gradual price increments are introduced so that it does not affect the economic growth in the country's three most significant sectors negatively.
ii. South Africa is still reliant on the mining sector, which accounts for 8% of the GDP and therefore, the negative impact of electricity price increases on the electricity consumption is detrimental to the economy as whole. Hence, it is recommended that the market for electricity supply is opened to competition and alternative energy so that the electricity prices can decrease. Consequently, it is recommended that electricity regulations should be amended to ensure that there is competition in the country's electricity grid and supply.
iii. Lastly, government should promote tax rebates for the use of equipment that is energy efficient to promote clean, sustainable energy as electricity prices affect major sectors that contribute significantly to the country's GDP.
iv. Policy-makers should increase the alternative energy supply limit from 1MW to 10MW so as to hasten electrification and industrialisation of the country's informal and rural residential sector.

6.4 Recommendations for future studies

There are two recommendations for further research:

i. The current study was conducted at national and sectoral level; however, it is recommended that future studies should investigate the relationship between electricity consumption, prices and economic growth further into the sub-sectors of each sector. For example, for services sector it can be divided into retail trade, insurance, banking and real estate—just to mention a few, as the impact of the electricity prices may differ among the sub-sectors. The purpose of this recommendation is that sub-sectors could be affected differently by electricity prices. Therefore, sub-sectors could provide more useful information about the impact of electricity prices on the economic growth.

ii. Further analysis can be done of the economic growth effects using an endogenous growth model (this will necessitate the inclusion of labour, schooling etc.).

iii. The study could be expanded to include other African countries so as to determine whether the relationships at a national level that have been found for South Africa also apply in other countries.

iv. Furthermore, recommendation is that Granger causality tests can be explored to determine the direction of causality in the model specification.

REFERENCES

Abbas, F., & Choudhury, N. (2013). Electricity consumption-economic growth Nexus: An aggregated and disaggregated causality analysis in India and Pakistan. *Journal of Policy Modeling*, *35*(4), 538–553. https://doi.org/10.1016/j.jpolmod.2012.09.001

Abokyi, E., Appiah-Konadu, P., Sikayena, I., & Oteng-Abayie, E. F. (2018). Consumption of Electricity and Industrial Growth in the Case of Ghana. *Journal of Energy*, 1–11. https://doi.org/10.1155/2018/8924835

Abosedra, S., Dah, A., & Ghosh, S. (2009). Electricity consumption and economic growth, the case of Lebanon. *Applied Energy*, *86*(4), 429–432. https://doi.org/10.1016/j.apenergy.2008.06.011

Adedokun, A. (2015). Can Electricity Consumption Be Useful in Predicting Nigerian Economic Growth? Evidence from Error Correction Model. *SSRN*, (2002), 125–141. https://doi.org/10.1111/opec.12042

Akobeng, E. (2017). Gross Capital Formation, Institutions and Poverty in Sub-Saharan Africa. *Journal of Economic Policy Reform*, *20*(2), 136–164. https://doi.org/10.1080/17487870.2015.1128833

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries. *Energy Economics*, *22*(6), 615–625. https://doi.org/10.1016/S0140-9883(00)00050-5

Bah, M. M., & Azam, M. (2017). Investigating the relationship between electricity consumption and economic growth: Evidence from South Africa. *Renewable and Sustainable Energy Reviews*, *80*(February), 531–537. https://doi.org/10.1016/j.rser.2017.05.251

Bayar, Y., & Ozel, H. A. (2014). Electricity consumption and economic growth in emerging economies. *Energy Policy*, *IV*(2), 125–129. https://doi.org/10.1016/S0301-4215(01)00078-7

Bélaïd, F., & Abderrahmani, F. (2013). Electricity consumption and economic growth in Algeria: A multivariate causality analysis in the presence of structural change. *Energy Policy*, *55*, 286–295. https://doi.org/10.1016/j.enpol.2012.12.004

Bildirici, M. (2012). Economic Growth and Electricity Consumption in Africa and Asia: MS-VAR and MS-Granger Causality Analysis. *SSRN*. https://doi.org/10.2139/ssrn.2129017

Bildirici, M. E., Bakirtas, T., & Fazil;, K. (2012). Economic growth and electricity consumption : Auto regressive distributed lag analysis. *Journal of Energy in Southern Africa*, *23*(4), 29–45.

Blignaut, J., Inglesi-Lotz, R., & Weideman, J. P. (2015). Sectoral electricity elasticities in South Africa: Before and after the supply crisis of 2008. *South African Journal of Science*, *111*(9–10), 1–7. https://doi.org/10.17159/sajs.2015/20140093

Blimpo, M. P., & Cosgrove-Davies, M. (2019). *Electricity Access in Sub-Saharan Africa Uptake, Reliability, and Complementary Factors for Economic Impact*. The World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/31333/9781464813610.pdf?deliveryName=DM10298

Bohlmann, J. A., & Inglesi-lotz, R. (2018). Analysing the South African residential sector's energy profile. *Renewable and Sustainable Energy Reviews*, *96*(June), 240–252. https://doi.org/10.1016/j.rser.2018.07.052

Campbell, A. (2018). Price and income elasticities of electricity demand: Evidence from Jamaica. *Energy Economics*, *69*, 19–32. https://doi.org/10.1016/j.eneco.2017.10.040

Chindarkar, N., & Goyal, N. (2019). One price doesn't fit all: An examination of heterogeneity in price elasticity of residential electricity in India. *Energy Economics*, *81*, 765–778. https://doi.org/10.1016/j.eneco.2019.05.021

Cialani, C., & Mortazavi, R. (2018). Household and industrial electricity demand in Europe. *Energy Policy*, *122*(April), 592–600. https://doi.org/10.1016/j.enpol.2018.07.060

Ciarreta, A., & Zarraga, A. (2010). Economic growth-electricity consumption causality in 12 European countries: A dynamic panel data approach. *Energy Policy*, *38*(7), 3790–3796. https://doi.org/10.1016/j.enpol.2010.02.058

Costantini, V., & Martini, C. (2010). The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegrated panel data.

Energy Economics, *32*(3), 591–603. https://doi.org/10.1016/j.eneco.2009.09.013

Creswell, J. W. (2014). *Research Design - Qualitative, quantitative and mixed methods approaches*. (V. Knight, Ed.) (Fourth Edi). Califonia: SAGE Publications, Inc.

Dagher, L., & Yacoubian, T. (2012). The causal relationship between energy consumption and economic growth in Lebanon. *Energy Policy*, *50*(2012), 795–801. https://doi.org/10.1016/j.enpol.2012.08.034

Deloitte. (2013). The Economic Impact of Electricity Price Increases on Various Sectors of the South African Economy, 108. Retrieved from http://www.eskom.co.za/CustomerCare/MYPD3/Documents/Economic_Impact_of_Electrcity_Price_Increases_Document1.pdf

Deloitte. (2017). An overview of electricity consumption and pricing in South Africa: An analysis of the historical trends and policies, key issues and outlook in 2017 Report prepared for Eskom Holdings SOC Ltd, (February), 1–86. Retrieved from http://www.eskom.co.za/Documents/EcoOverviewElectricitySA-2017.pdf

Department of Energy (RSA). (2012). Department of Energy Draft 2012 Integrated Energy Planning Report Annexure a – Technical Report.

Department of Minerals and Energy. (1998). *White Paper on the Energy Policy*.

Dlamini, J., Balcilar, M., Gupta, R., & Lotz, R. I. (2015). Revisiting the causality between electricity consumption and economic growth in South Africa: a bootstrap rolling-window approach. *International Journal of Economic Policy in Emerging Economies*, *8*(2), 169. https://doi.org/10.1504/ijepee.2015.069595

Durbin, B. Y. J., & Watson, G. S. (1950). Testing for Serial Correlation in Least Squares Regression : I. *Biometrika*, *37*(3), 409–428.

Eberhard, A. (2005). From State to Market and Back Again: South Africa's power sector reforms. *Economic and Political Weekly*, *40*(50), 5309–5317.

Eskom - Annual financial statements. (2018). AFS.

Eskom Revenue application MYPD 4. (2018). Multi-Year Price Determination, (September). Retrieved from www.eskom.co.za

Esso, L. J. (2010). Threshold cointegration and causality relationship between energy use and growth in seven African countries. *Energy Economics*, *32*(6), 1383–1391. https://doi.org/10.1016/j.eneco.2010.08.003

Faisal, F., Tursoy, T., Gunsel Resatoglu, N., & Berk, N. (2018). Electricity consumption, economic growth, urbanisation and trade nexus: empirical evidence from Iceland. *Economic Research-Ekonomska Istrazivanja* , *31*(1), 664–680.

https://doi.org/10.1080/1331677X.2018.1438907

Fetahi-Vehapi, M., Sadiku, L., & Petkovski, M. (2015). Empirical Analysis of the Effects of Trade Openness on Economic Growth: An Evidence for South East European Countries. *Procedia Economics and Finance*, *19*(15), 17–26. https://doi.org/10.1016/s2212-5671(15)00004-0

Frondel, M., Kussel, G., & Sommer, S. (2019). Heterogeneity in the Price Response of Residential Electricity Demand: A Dynamic Approach for Germany. *Resource and Energy Economics*, *57*, 119–134. https://doi.org/10.1016/j.reseneeco.2019.03.001

Gautam, T. K., & Paudel, K. P. (2018). Estimating sectoral demands for electricity using the pooled mean group method. *Applied Energy*, *231*(March), 54–67. https://doi.org/10.1016/j.apenergy.2018.09.023

Golam Ahamad, M., & Nazrul Islam, A. K. M. (2011). Electricity consumption and economic growth nexus in Bangladesh: Revisited evidences. *Energy Policy*, *39*(10), 6145–6150. https://doi.org/10.1016/j.enpol.2011.07.014

Gonese, D., Hompashe, D., & Sibanda, K. (2019). The impact of electricity prices on sectoral output in South Africa from 1994 to 2015. *African Journal of Economic and Management Studies*. https://doi.org/10.1108/AJEMS-12-2017-0305

Ibrahiem, D. M. (2018). Investigating the causal relationship between electricity consumption and sectoral outputs: evidence from Egypt. *Energy Transitions*, *2*(1–2), 31–48. https://doi.org/10.1007/s41825-018-0009-8

IEA. (2018). Electricity Information 2018: Overview. Retrieved from https://webstore.iea.org/electricity-information-2018-overview

Inglesi-Lotz, R., & Pouris, A. (2016). On the causality and determinants of energy and electricity demand in South Africa: A review. *Energy Sources, Part B: Economics, Planning and Policy*, *11*(7), 626–636. https://doi.org/10.1080/15567249.2013.801536

Inglesi-Lotz, Roula, & Blignaut, J. (2011). Estimating the price elasticity for demand for electricity by sector in South Africa. *South African Journal of Economic and Management Sciences*, *14*(4), 449–465. https://doi.org/10.4102/sajems.v14i4.134

Inglesi, R., & Blignaut, J. N. (2011). South Africa's electricity consumption: A sectoral decomposition analysis Inglesi, Roula. *South Africa's Electrcity Consumption: A Sectoral Decomposition Analysis*, *27*(February), 2–16. Retrieved from http://www.econrsa.org/papers/w_papers/wp203.pdf

International Renewable Energy Agency (IRENA). (2015). Africa 2030: Roadmap for a renewable energy future, REmap 2030 programme.

Inuwa, N., Adamu, S., Saidu, A. M., & Sani, M. B. (2019). Dynamic panel modelling of electricity consumption and economic growth in economic community of West African States. *OPEC Energy Review*, 1–14. https://doi.org/10.1111/opec.12150

Iyke, B. N. (2015). Electricity consumption and economic growth in Nigeria: A revisit of the energy-growth debate. *Energy Economics*, *51*, 166–176. https://doi.org/10.1016/j.eneco.2015.05.024

J. Cameron, M., & Rossouw, R. (2012). Modelling the Economic Impact of Electricity Tariff Increases on Eskom's Top Customer Segment. *International Journal of Energy Engineering*, *2*(6), 315–331. https://doi.org/10.5923/j.ijee.20120206.06

Jonker, J., & Pennink, B. (2010). *The essence of research methodology - A concise guide for master and PhD students in Management Science*. New York: Springer Heidelberg Dordrecht. https://doi.org/10.1007/978-3-540-71659-4

Karanfil, F., & Li, Y. (2015). Electricity consumption and economic growth: Exploring panel-specific differences. *Energy Policy*, *82*(1), 264–277. https://doi.org/10.1016/j.enpol.2014.12.001

Kasperowicz, R. (2014). Electricity consumption and economic growth: evidence from Poland. *Journal of International Studies*, *7*(1), 46–57. https://doi.org/10.17811/ebl.2.1.2013.21-32

Khalid, W., & Khan, S. (2017). Effects of Macroeconomic Variables on the Stock Market Volatility: The Pakistan Experience. *International Journal of Econometrics and Financial Management*, *5*(2), 42–59. https://doi.org/10.12691/ijefm-5-2-4

Liew, K. S., Nathan, T. M., & Wong, W. K. (2012). Are sectoral outputs in Pakistan led by energy consumption? *Economics Bulletin*, *32*, 2323–2331.

Lin, B., & Wesseh, P. K. (2014). Energy consumption and economic growth in South Africa reexamined: A nonparametric testing apporach. *Renewable and Sustainable Energy Reviews*, *40*, 840–850. https://doi.org/10.1016/j.rser.2014.08.005

Lu, W. C. (2017). Electricity consumption and economic growth: Evidence from 17 Taiwanese industries. *Sustainability (Switzerland)*, *9*(1). https://doi.org/10.3390/su9010050

Marinaş, M. C., Dinu, M., Socol, A. G., & Socol, C. (2018). Renewable energy consumption and economic growth. Causality relationship in Central and Eastern European countries. *PLoS ONE*, *13*(10), 1–29. https://doi.org/10.1371/journal.pone.0202951

Mawejje, J., & Mawejje, D. N. (2016). Electricity consumption and sectoral output in Uganda: an empirical investigation. *Journal of Economic Structures*, *5*(1).

https://doi.org/10.1186/s40008-016-0053-8

Mazambani, F. R. (2015). *The impact of electricity pices on economic growth: A case study of South Africa*. University of Fort Hare.

Mozumder, P., & Marathe, A. (2007). Causality relationship between electricity consumption and GDP in Bangladesh. *Energy Policy*, *35*(1), 395–402. https://doi.org/10.1016/j.enpol.2005.11.033

Mpatane, L. M. (2015). *The Impact of Electricity Supply on the Manufacturing Sector Output in South Africa*. North West University.

Mugano, G., Le Roux, P., & Khobai, H. (2017). The causal relationship between electricity supply and economic growth in South Africa. *Journal for Studies in Economics and Econometrics*, *41*(2), 69–86.

Mungendje, L. (2017). *The causal relationship between road infrastructure development and economic growth in Nambia (1990-2014)*. Graduate School of Business, Universityof Cape Town.

Nathan, T. M., & Liew, V. K. (2013). Does Electricity Consumption have Significant Impact towards the Sectoral Growth of Cambodia? Evidence from Wald Test Causality Relationship, *1*(2), 59–66.

Nazlioglu, S., Kayhan, S., & Adiguzel, U. (2014). Electricity consumption and economic growth in Turkey: Cointegration, linear and nonlinear granger causality. *Energy Sources, Part B: Economics, Planning and Policy*, *9*(4), 315–324. https://doi.org/10.1080/15567249.2010.495970

NDP. (2013). National Development Plan. https://doi.org/ISBN: 978-0-621-41180-5

Nersa decision: Eskom RCA and MYPD 4 Determination. (n.d.). NERSA's decision on Eskom's regulatory clearing account application for Year 5 (2017/18) and Eskom's fourth Multi-Year Price determination for 2019/20 to 2021/22.

Nkoro, E., & Uko, A. K. (2016). Autoregressive Distributed Lag (ARDL) cointegration technique : application and interpretation. *Journal of Statistical and Econometric Methods*, *5*(4), 63–91. https://doi.org/10.1002/jae.616

Odhiambo, N. M. (2009). Electricity consumption and economic growth in South Africa: A trivariate causality test. *Energy Economics*, *31*(5), 635–640. https://doi.org/10.1016/j.eneco.2009.01.005

Ohlan, R. (2018). The relationship between electricity consumption, trade openness and economic growth in India. *OPEC Energy Review*, *42*(4), 331–354. https://doi.org/10.1111/opec.12134

Osman, M., Gachino, G., & Hoque, A. (2016). Electricity consumption and economic growth in the GCC countries: Panel data analysis. *Energy Policy*, *98*, 318–327. https://doi.org/10.1016/j.enpol.2016.07.050

Ould, L. (2015). An Investigation of the Impact of Foreign Direct Investment on Economic Growth: A Case Study of Mauritania. *International Journal of Economics & Management Sciences*, *04*(02). https://doi.org/10.4172/2162-6359.1000224

Payne, J. E. (2010). A survey of the electricity consumption-growth literature. *Applied Energy*, *87*(3), 723–731. https://doi.org/10.1016/j.apenergy.2009.06.034

Pei, T. L., Shaari, T. S., & Ahmad, T. S. T. (2016). The effects of electricity consumption on agriculture, service and manufacturing sectors in Malaysia. *International Journal of Energy Economics and Policy*, *6*(3), 401–407. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84979240866&partnerID=40&md5=f0c1e81910ab39f1401afb7b255e79b2

Perron, P. (1986). The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. *Econometrica*, *57*(6), 1361–1401. https://doi.org/10.2307/1913712

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326. https://doi.org/10.1002/jae.616

Pollet, B. G., Staffell, I., & Adamson, K. A. (2015). Current energy landscape in the Republic of South Africa. *International Journal of Hydrogen Energy*, *40*(46), 16685–16701. https://doi.org/10.1016/j.ijhydene.2015.09.141

Reserve Bank (SA). (2017). The evolution of gross fixed capital formation, (June), 18–20.

Sadikova, M., Faisal, F., & Resatoglu, N. G. (2017). Influence of energy use, foreign direct investment and population growth on unemployment for Russian Federation. *Procedia Computer Science*, *120*, 706–711. https://doi.org/10.1016/j.procs.2017.11.299

Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries? *Energy Economics*, *37*, 52–59. https://doi.org/10.1016/j.eneco.2013.01.009

Saidi, S., Shahbaz, M., & Akhtar, P. (2018). The long-run relationships between transport energy consumption , transport infrastructure , and economic growth in MENA countries. *Transportation Research Part A*, *111*(October 2017), 78–95. https://doi.org/10.1016/j.tra.2018.03.013

Samu, R., Bekun, F. V., & Fahrioglu, M. (2019). Electricity consumption and economic growth nexus in Zimbabwe revisited: fresh evidence from Maki cointegration.

International Journal of Green Energy, *16*(7), 540–550. https://doi.org/10.1080/15435075.2019.1598417

Sankaran, A., Kumar, S., K, A., & Das, M. (2019). Estimating the causal relationship between electricity consumption and industrial output: ARDL bounds and Toda-Yamamoto approaches for ten late industrialized countries. *Heliyon*, *5*(6), e01904. https://doi.org/10.1016/j.heliyon.2019.e01904

Sekantsi, L. P., & Okot, N. (2016). Electricity consumption–economic growth nexus in Uganda. *Energy Sources, Part B: Economics, Planning and Policy*, *11*(12), 1144–1149. https://doi.org/10.1080/15567249.2015.1010022

Sekantsi, L. P., & Thamae, R. I. (2016). Electricity consumption and economic growth in Lesotho. *Energy Sources, Part B: Economics, Planning and Policy*, *11*(10), 969–973. https://doi.org/10.1080/15567249.2013.876125

Sen, K. (2019). What Explains the Job Creating Potential of Industrialisation in the Developing World? *Journal of Development Studies*, *55*(7), 1565–1583. https://doi.org/10.1080/00220388.2017.1404033

Shahbaz, M., Sarwar, S., Chen, W., & Malik, M. N. (2017). Dynamics of electricity consumption, oil price and economic growth: Global perspective. *Energy Policy*, *108*(March), 256–270. https://doi.org/10.1016/j.enpol.2017.06.006

Solarin, S. A. (2011). Electricity Consumption and Economic Growth: Trivariate Investigation in Botswana with Capital Formation. *International Journal of Energy Economics and Policy*, *1*(January 2011), 32–46. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=econ&AN=1287569

Statistics SA. (2017). General household survey.

Su, D., & Yao, Y. (2017). Manufacturing as the key engine of economic growth for middle-income economies. *Journal of the Asia Pacific Economy*, *22*(1), 47–70. https://doi.org/10.1080/13547860.2016.1261481

Tamba, J. G., Nsouandélé, J. L., Fopah Lélé, A., & Sapnken, F. E. (2017). Electricity consumption and economic growth: Evidence from Cameroon. *Energy Sources, Part B: Economics, Planning and Policy*, *12*(11), 1007–1014. https://doi.org/10.1080/15567249.2017.1349211

Tang, C. F., & Shahbaz, M. (2013). Sectoral analysis of the causal relationship between electricity consumption and real output in Pakistan. *Energy Policy*, *60*, 885–891. https://doi.org/10.1016/j.enpol.2013.05.077

Tariq, G., Sun, H., Haris, M., Javaid, H. M., & Kong, Y. (2018). Energy Consumption and Economic Growth : Evidence fom four developing countries. *American Journal of Mutlidisplinary Research*, *7*(1). Retrieved from https://www.semanticscholar.org/paper/ENERGY-CONSUMPTION-AND-ECONOMIC-GROWTH-%3A-EVIDENCE-Nondo-Schaeffer/69462de61cbf0b26e72516b5055c718d65c5f9f6

Tham, S. Y. (2017). Examining the Shift to Services: Malaysia and China Compared. *Journal of Contemporary Asia*, *47*(5), 728–751. https://doi.org/10.1080/00472336.2017.1310273

Wang, N., & Mogi, G. (2017). Industrial and residential electricity demand dynamics in Japan: How did price and income elasticities evolve from 1989 to 2014? *Energy Policy*, *106*(March), 233–243. https://doi.org/10.1016/j.enpol.2017.03.066

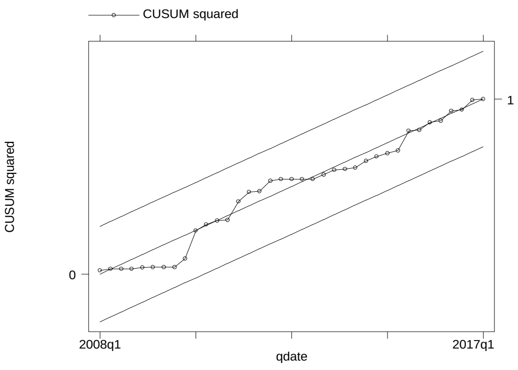
Wolde-Rufael, Y. (2006). Electricity consumption and economic growth: A time series experience for 17 African countries. *Energy Policy*, *34*(10), 1106–1114. https://doi.org/10.1016/j.enpol.2004.10.008

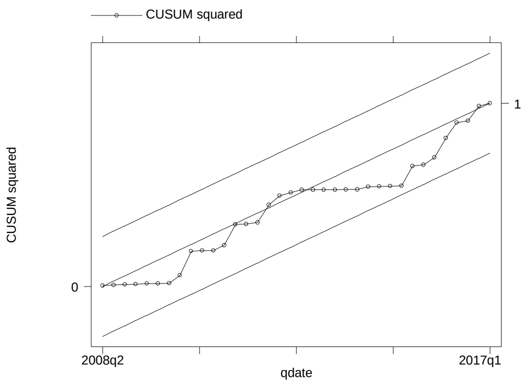
Wu, Y., & Chen, C. (2016). The impact of foreign direct investment on urbanization in China. *Journal of the Asia Pacific Economy*, *21*(3), 339–356. https://doi.org/10.1080/13547860.2016.1176641

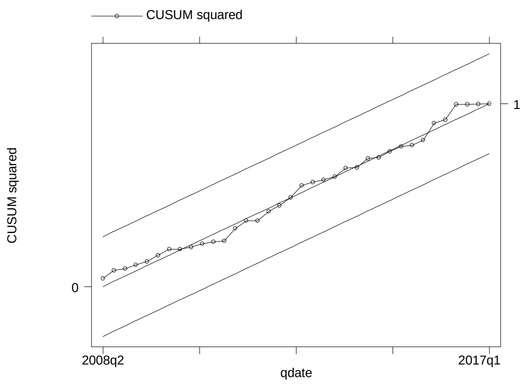
Zhang, C., Zhou, K., Yang, S., & Shao, Z. (2017). On electricity consumption and economic growth in China. *Renewable and Sustainable Energy Reviews*, *76*(February), 353–368. https://doi.org/10.1016/j.rser.2017.03.071

APPENDICES

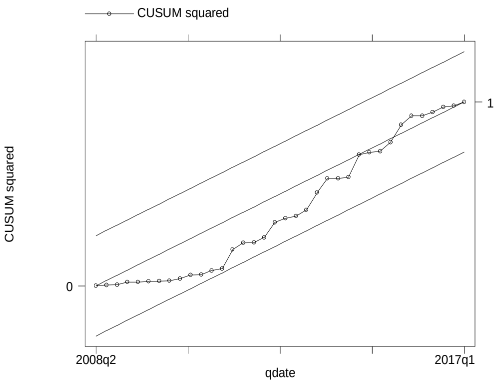
Appendix A: CUSUM Results

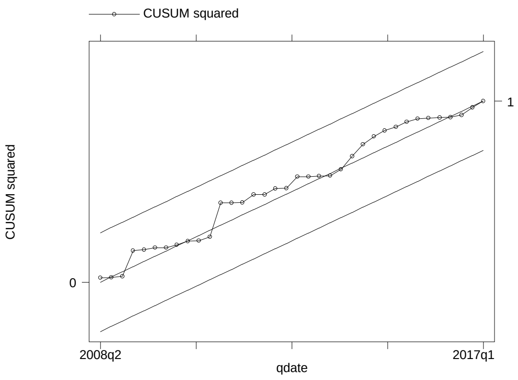


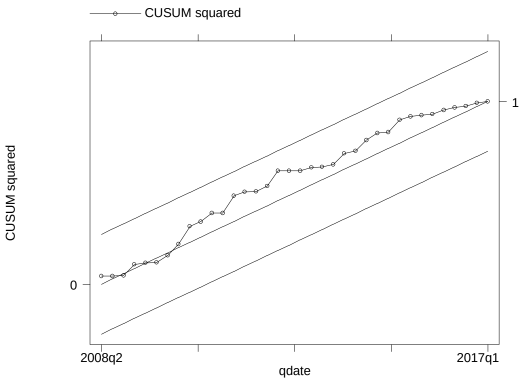




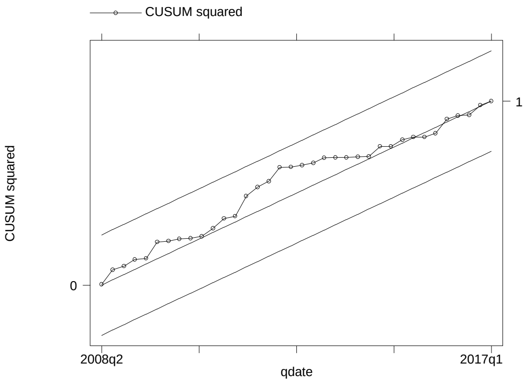
National - Electricity Consumption   National - Electricity Price   National - GDP

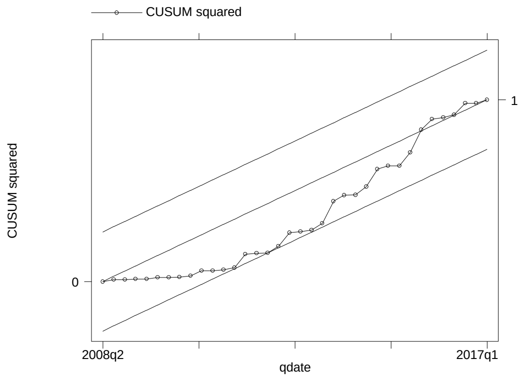


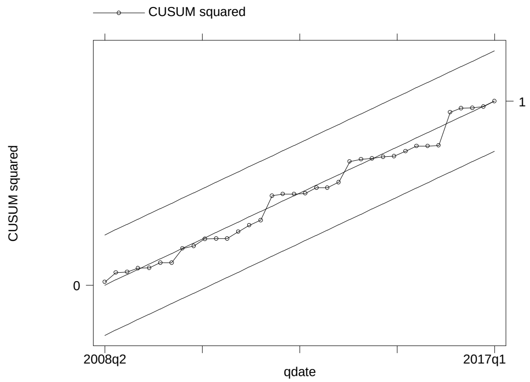




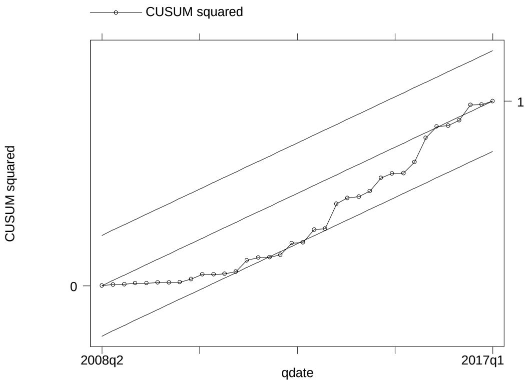
Services – Electricity Price Services – Electricity Consumption Services - GDP

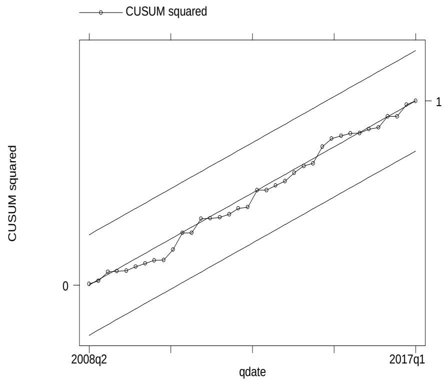


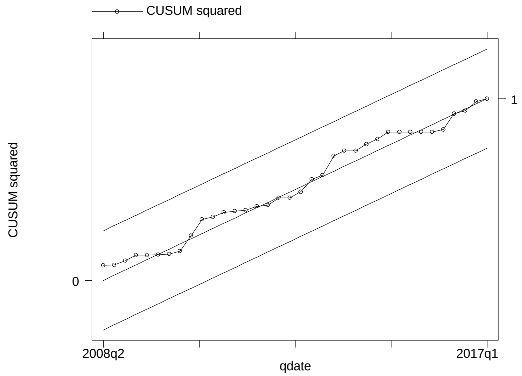




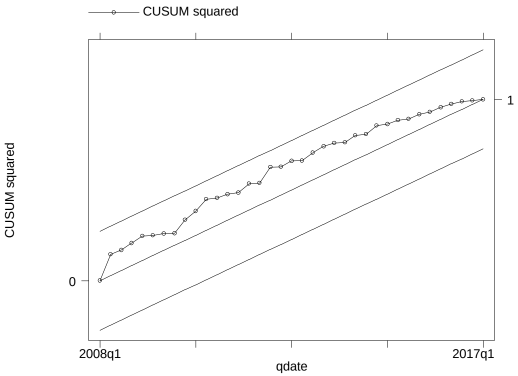
Mining – Electricity consumption Mining – Electricity Price Mining - GDP



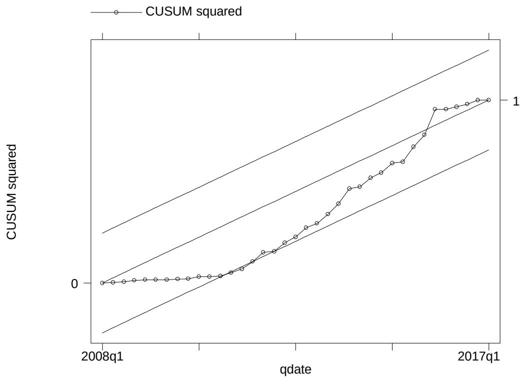




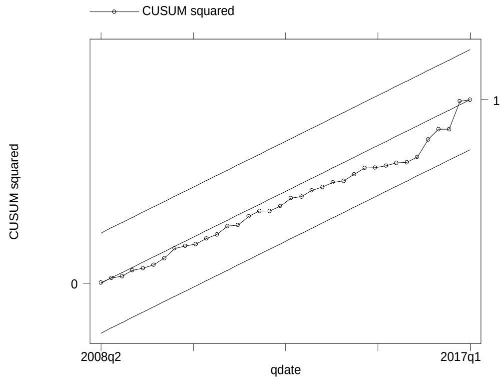
Transport – Electricity Price Transport – Electricity Consumption Transport - GDP



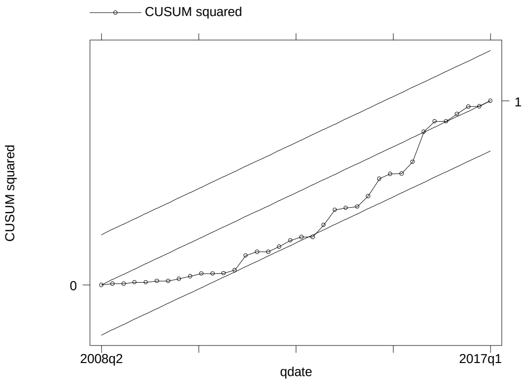
Residential – Electricity Consumption



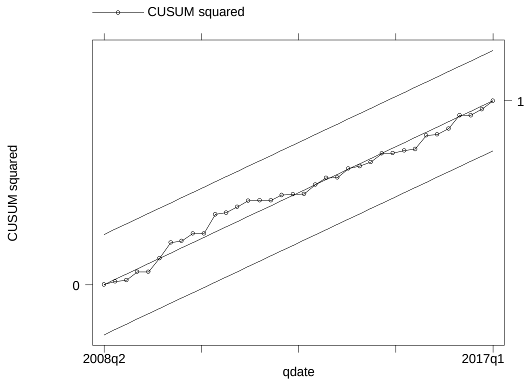
Residential – Electricity Price



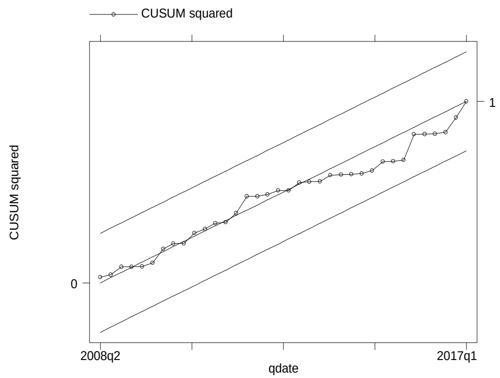
Industrial – Electricity Consumption



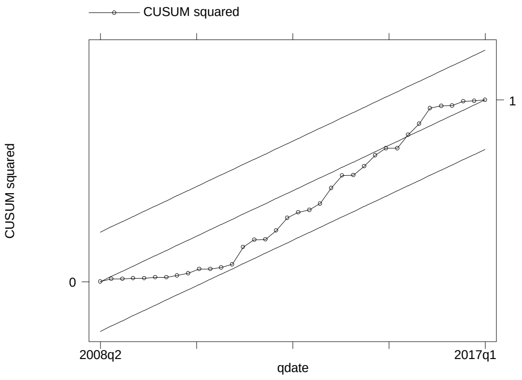
Industrial – Electricity Prices



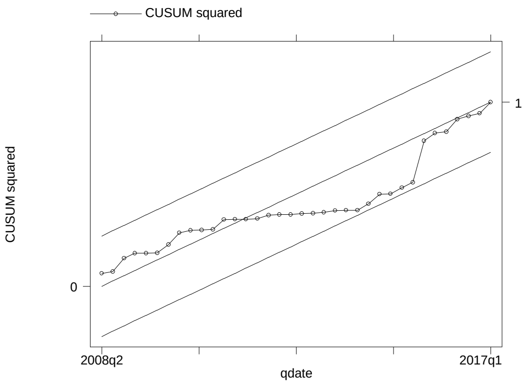
Industrial – GDP



Agriculture – Electricity Consumption



Agriculture – Electricity Prices



Agriculture - GDP